

Assessment of different casing materials for use as peat alternatives in mushroom cultivation. Evaluation of quantitative and qualitative production parameters

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Abstract

In this work, various casing materials (composted pine bark, coconut fibre pith and wood fibre) have been evaluated as alternative to peat (*sphagnum* blonde peat and black peat) for the cultivation of mushroom. For this, both quantitative (number of mushrooms, yield, unit weight, biological efficiency and earliness) and qualitative (diameter of the sporophore, colour, dry matter, texture, proteins, soluble solids, ash and pH) production parameters were evaluated. The results obtained for the number of mushrooms, unit weight, total production, biological efficiency, diameter of the sporophore, colour, dry matter, protein, soluble solid and ash content, and pH, differed among the three mushroom strains considered. The greatest proportion of harvested mushrooms were of medium size for all strains and casing layers considered. No significant differences were observed in colour and texture among the casing types.

Key words: *Agaricus bisporus*, casing layer, fruiting.

Resumen

Ensayo de diferentes materiales de cobertura como alternativa a las turbas en el cultivo del champiñón. Evaluación de parámetros de producción cuantitativos y cualitativos.

En este trabajo se evaluaron diferentes materiales de cobertura (corteza de pino compostada, fibra de coco y fibra de madera) como alternativa a las turbas (turba rubia y turba negra) en el cultivo del champiñón, en cuanto a parámetros de producción cuantitativos (número de champiñones, rendimiento, peso unitario, eficiencia biológica y precocidad) y cualitativos (diámetro del carpóforo, color, materia seca, textura, proteínas, sólidos solubles, cenizas y pH). Los resultados obtenidos en cuanto al número de champiñones, peso unitario, producción total, eficiencia biológica, diámetro del carpóforo, color (L^* , ΔE^*), contenidos en materia seca, proteínas, sólidos solubles y cenizas, y pH, han sido dispares en función del experimento (semilla) considerado. En cuanto a la categoría comercial del champiñón cultivado, la mayor proporción correspondió al champiñón mediano, en todos los experimentos y para todas las capas de cobertura consideradas. En cuanto a la precocidad, color (b^*) y textura, no se observaron diferencias significativas entre tipos de cobertura en ninguno de los experimentos realizados.

Palabras clave: *Agaricus bisporus*, capa de cobertura, fructificación.

Introduction

The mushroom *Agaricus bisporus* (Lange) Imbach is the most widely cultivated fungus in Spain and throughout the world, where it is grown commercially in at least 80 countries. The European Union, especially Holland and France, is responsible for 46% of world production, followed by North America (25%) and Asia with 21% (ANICC, 1995).

The initiation and growth of mushroom sporophores depend not only on the genetic capacity of the mycelium to yield fruit, but also on physical, environmental, chemical, nutritive and microbiological factors (Pardo *et al.*, 2002a, b). In commercial cultivation, the fruit bodies appear on the casing material which is used to cover the compost after the germination phase in order to induce the transition from vegetative to productive growth. This transition determines the commercial viability of the crop.

The casing material has several roles (Bazerque and Laborde, 1975; Visscher, 1988; Wuest and Beyer,

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1996), among which it: (1) constitutes the physical support in which the sporophores can develop; (2) maintains the correct degree of humidity; (3) acts as a medium for stimulatory bacteria; (4) protects the surface of the compost from drying out; (5) provides a suitably aerated environment for the mycelium, encouraging gas interchanges, and (6) provides an environment of low osmotic value.

In the Manchuela district, where 45-50% of Spanish production is concentrated, several kinds of peat, in combination with soils from various origins, are the most widely used casing material, mainly due to their high water holding capacity and excellent structural properties (Yeo and Hayes, 1979). However, because of difficulties of supply, principally related with the alteration of ecosystems and diminishing availability, alternatives must be considered.

For this reason, we analysed five casing materials (soil+*sphagnum* peat, soil+black peat, soil+pine bark, soil+coconut fibre pith and soil+wood fibre), looking at quantitative (number of mushrooms, yield, unit weight, biological efficiency and earliness) and qualitative (diameter of the sporophore, colour, dry matter, texture, proteins, soluble solids, ash and pH) production parameters.

Material and Methods

Individual experiments were carried out with three commercial strains of mushroom: Pla 8.9, a mid-range hybrid, supplied by Pla Micelios de Champiñón y Setas S.A.T. (Arganda del Rey, Madrid); Blancochamp BL-40, a smooth white hybrid, supplied by Micelios Blancochamp S.L. (Valverde del Júcar, Cuenca) and Gurelan 45, a large off-white hybrid, supplied by Gurelan S.C. (Huarte-Pamplona, Navarra). A spawn rate of 12 g kg⁻¹ pasteurized mushroom compost was used. For each spawn type, a total of 40 experimental trays (eight for each kind of casing) were distributed into four blocks at two levels on both sides of the cropping culture chamber. Each tray, of surface area of 870 cm², was filled with 6 kg of compost compacted at 450 kg m⁻³.

Wheat straw and poultry manure-based commercial compost were used (Champ-Rey SCL, Quintanar del Rey, Cuenca). The analytical characteristics were as follows: 65.9-68.9% moisture content, 73.5-77.4% organic matter content, 2.2-2.4% total nitrogen content, a C/N ratio of 18.4-19.6, pH 7.2-7.5 and ash content of 22.6-26.5%. All the values were adjusted to the ran-

ge considered optimal for mushroom cultivation (Vedder, 1978; Pardo, 1993; Hearne, 1994).

The five casing layers used were binary combinations with soil of *sphagnum* blonde peat (S+SP), black peat (S+BP), composted pine bark (S+PB), coconut fibre (S+CF) and wood fibre (S+WF) in a proportion of 4:1 (v v⁻¹). The thickness of the casing was 3 cm, which represented 2.6 L of material per tray.

The experiments were carried out in a 20 m³ experimental walk-in growth chamber, provided with humidification system, a heating/cooling system and internal air circulation/outside ventilation. The growth cycles were carried out according to the growth chamber conditions (air temperature, relative humidity and carbon dioxide concentration) suggested for each of the selected strains (CIES, 2000). A spawn run period of 14 days was used, and the usual disinfectant (formalin, 18 ml m⁻²), insecticidal (diflubenzuron 25%, 3.6 g m⁻²) and fungicidal (prochloraz 46%, 0.62 g m⁻²) treatments were applied after casing. Each cultivation cycle lasted 80 days.

Mushrooms were harvested every day at their optimal commercial stage of development, corresponding to morphogenetic stages 2, 3 and 4, according to the classification established by Hammond and Nichols (1976).

To assess the production parameters, the weight before stipe trimming and the total number of mushrooms picked from each selected tray each day were recorded. Yield is expressed by reference to the cultivated area and the quantity of compost used (biological efficiency). Total mushroom production was separated into three groups according to size and defects: (1) large size mushrooms of prime quality (≥ 40 mm); (2) medium sized mushrooms of prime quality (< 40 mm) and mushrooms showing defects of shape or colour, or symptoms of disease (unmarketable mushrooms).

The size of the mushrooms, expressed as unit weight (g) was calculated from the yield and the number of harvested mushrooms. Earliness was expressed as the number of days between casing and the harvest of the first flush.

To evaluate the quality parameters, mushrooms of a uniform size and stage of maturity were selected on the day of maximum harvest for each of the first three flushes. For the overall evaluation of these parameters the weighted means were calculated for the relative yield of each of the first three flushes.

The surface colour of mushrooms was measured using a Minolta Chroma Meter CR-300 (Minolta

Camera Co., Ltd., Osaka, Japan), with CIE Standard Illuminant D₆₅ as light source. Before measurement, the instrument was calibrated with a standard white plate (Calibration Plate CR-A43; L* = 96.12, a* = -0.11, b* = +2.66; Minolta Camera Co., Ltd., Osaka, Japan). Twenty measurements were taken in each of the first three flushes for each tray, namely four measurements on the cap surface of five disease-free mushrooms of uniform size. The first measurement was made in the centre of the cap and the other three between 1 and 2 cm from the first, depending on the size of the fruit bodies. To describe the colour reference was made to the chromatic coordinates L* (luminosity) and b* (yellow-blue component) and the chromatic attribute ΔE^* , which measures the degree of deviation compared with the values of an ideal sporophore (Roy *et al.*, 1995).

The dry matter content (g kg⁻¹) was measured as the loss of weight after desiccation at 105°C (MAPA, 1994) in a Selecta Digitronic forced air oven (J.P. Selecta, S.A., Abrera, Barcelona).

Texture was measured as the compression force (Newtons, N) using a fruit dial penetrometer (Fruit Pressure Tester PT 011 from Bertuzzi, Alfonsine, Italy) based on the Magness-Taylor penetrometer with a 6.4 mm (1/4") diameter cylindrical punch. Measurements were made in the caps (in the centre and at 1-2 cm distance, depending on the size) of five mushrooms from each tray and for each of the first three flushes.

Protein content (g kg⁻¹) was calculated as the product of total nitrogen content and a conversion factor of 4.38 (Delmas, 1989). The total nitrogen content was obtained by Kjeldahl's method (MAPA, 1994) using a Tecnit D-12 digester (Tecnología Ibérica de Laboratorio, S.L., Madrid) and an automatic Kjeltac Auto 1030 Analyser from Tecator AB (Höganäs, Sweden).

The soluble solids (SS) content, expressed in °Brix, was determined by refractometer (Tateo, 1979) using a Palette PR-100 digital refractometer (Atago Co. Ltd., Tokio, Japan). This parameter was determined separately in foot and cap in quadruplicate, taking portions from at least four mushrooms from each flush and extracting the juice by a domestic garlic press (Laifa S.A., Montornés del Vallés, Barcelona). The final SS content of each sample was calculated by attributing 80% to the cap and 20% to the stipe.

The pH was determined by directly puncturing the caps using a Xerolit penetration electrode (Cat. no. 52-32, de Crison Instruments S.A., Alella, Barcelona) coupled to a Crison microph 2001 pH-meter (Crison Instruments S.A., Alella, Barcelona).

Sporophores were ashed at 540°C (MAPA, 1994) in a Selecta-Horn electric muffle oven (J.P. Selecta S.A., Abrera, Barcelona). Ash content is expressed in g kg⁻¹.

Statistical analyses were performed with Statgraphics Plus 4.1 (Statistical Graphics Corp., Princeton, NJ, USA) with significant differences established by the Tukey-HSD test (p = 0.05).

Results and Discussion

The mean values of the various quantitative production parameters for the three spawn types and five casing combinations are presented in Table 1.

In Experiment 1 the greatest number of mushrooms was obtained using soil+coconut fibre, although the difference was only significant between this mixture and soil+wood fibre. In the other two experiments soil+pine bark produced the greatest number of mushrooms, in both cases a significant difference with soil+wood fibre. In Experiment 3, this treatment also showed a significant difference with soil+*sphagnum* peat.

No significant differences were observed in unit weight between casings in Experiment 1. In Experiments 2 and 3 sporophores were larger in the mixture containing wood fibre, although a significant difference was only observed between this mixture and those containing black peat and pine bark.

Overall production responded to the casing material and strain. The best combination was the casing containing soil and coconut fibre in the case of Pla 8.9, with significant differences between this and the casings containing *sphagnum* peat and wood fibre. When Blancochamp BL-40 was used, wood fibre produced the worst results but with no significant differences with black peat, while Gurelan 45 showed no significant differences between casings. As regards the commercial category of the cultivated mushrooms, the greatest proportion was of medium size, while there were no significant differences between the casings in any of the experiments in relation to the proportion of large size mushrooms.

Taking into account that the biological efficiency is established from the yield per surface area unit and the load density of compost in the trays, all the considerations made to the total yield are applicable for the biological efficiency.

As for earliness, no differences were seen between the casing types in any of the experiments.

Table 1. Mean values of the quantitative production parameters considered¹

Experiment	Casing	Number of mushrooms m ⁻²	Unitary weight (g mushroom ⁻¹)	Mushroom yield (kg m ⁻²)					Biological efficiency (kg 100 kg ⁻¹ compost)	Earliness (days from casing)
				Marketable mushrooms			Non-marketable mushrooms	Total production		
				Large size (≥40 mm)	Medium size (<40 mm)	Total marketable				
1 (strain Pla 8.9)	1 (S+SP)	1,312 ab	13.5 a	5.54 a	11.86 ab	17.39 bc	0.18 a	17.58 bc	25.49 bc	27.1 a
	2 (S+BP)	1,519 ab	12.3 a	4.85 a	13.25 ab	18.09 abc	0.17 a	18.26 abc	26.48 abc	27.6 a
	3 (S+PB)	1,649 a	12.5 a	5.94 a	13.80 a	19.74 ab	0.16 a	19.90 ab	28.85 ab	26.5 a
	4 (S+CF)	1,685 a	12.6 a	6.30 a	14.51 a	20.81 a	0.13 a	20.94 a	30.36 a	27.0 a
	5 (S+WF)	1,121 b	14.3 a	5.23 a	10.31 b	15.54 c	0.29 a	15.83 c	22.96 c	27.1 a
2 (strain Blancochamp BL-40)	1 (S+SP)	1,737 ab	12.6 ab	6.97 a	14.26 ab	21.23 a	0.18 a	21.41 a	31.04 a	24.8 a
	2 (S+BP)	1,792 a	12.0 b	5.91 a	14.98 a	20.89 a	0.03 a	20.92 ab	30.33 ab	24.4 a
	3 (S+PB)	2,010 a	11.4 b	6.14 a	16.50 a	22.63 a	0.21 a	22.84 a	33.12 a	24.0 a
	4 (S+CF)	1,805 a	12.7 ab	7.66 a	14.57 ab	22.23 a	0.26 a	22.49 a	32.60 a	24.6 a
	5 (S+WF)	1,330 b	14.4 a	7.18 a	11.52 b	18.70 b	0.10 a	18.79 b	27.25 b	25.7 a
3 (strain Gurelan 45)	1 (S+SP)	1,158 b	15.5 ab	7.70 a	9.88 ab	17.58 a	0.17 b	17.75 a	25.74 a	27.4 a
	2 (S+BP)	1,448 a	13.1 b	5.20 a	13.29 a	18.50 a	0.11 b	18.61 a	26.98 a	28.1 a
	3 (S+PB)	1,497 a	13.5 b	5.96 a	13.13 a	19.09 a	0.86 a	19.95 a	28.93 a	26.4 a
	4 (S+CF)	1,325 ab	15.6 ab	7.81 a	12.28 ab	20.09 a	0.33 b	20.42 a	29.61 a	26.7 a
	5 (S+WF)	1,088 b	16.5 a	8.06 a	9.25 b	17.31 a	0.51 ab	17.81 a	25.83 a	26.8 a

¹ Values followed by a different letter within a column and experiment are significantly different at 5% level according to Tukey's test. S+SP: soil + *sphagnum* blonde peat (4:1, v v⁻¹). S+PB: soil + composted pine bark (4:1, v v⁻¹). S+WF: soil + wood fibre (4:1, v v⁻¹). S+BP: soil + black peat (4:1, v v⁻¹). S+CF: soil + coconut fibre pith (4:1, v v⁻¹).

Table 2. Mean values of the qualitative production parameters considered¹

Experiment	Casing	Diameter of the sporophore (mm)	Colour			Dry matter (%)	Firmness (N)	Protein (%)	Soluble solids (°Brix)	Ash (%)	pH
			L*	b*	ΔE*						
1 (strain Pla 8.9)	1 (S+SP)	32.9 a	93.74 b	9.63 a	10.35 a	7.72 a	15.8 a	25.31 a	5.06 ab	12.71 bc	6.86 a
	2 (S+BP)	31.7 a	94.62 a	8.88 a	9.34 b	7.68 a	16.3 a	24.05 a	5.29 a	12.53 c	6.83 a
	3 (S+PB)	31.8 a	94.09 ab	9.46 a	10.07 ab	7.16 ab	15.0 a	24.23 a	4.65 bc	13.45 a	6.87 a
	4 (S+CF)	32.0 a	94.26 ab	9.02 a	9.61 ab	6.97 b	15.4 a	23.86 a	4.39 c	13.33 ab	6.89 a
	5 (S+WF)	33.6 a	93.63 b	9.30 a	10.07 ab	7.72 a	16.3 a	24.83 a	5.11 ab	11.83 d	6.89 a
2 (strain Blancochamp BL-40)	1 (S+SP)	32.8 ab	93.19 b	9.62 a	10.59 a	8.33 bc	20.3 a	26.19 a	5.26 b	11.20 a	6.82 a
	2 (S+BP)	32.2 b	93.92 a	9.42 a	10.12 a	8.91 ab	21.8 a	24.43 ab	6.02 a	10.92 ab	6.75 ab
	3 (S+PB)	31.7 b	93.70 ab	9.24 a	10.05 a	8.05 c	19.8 a	24.88 ab	5.13 b	11.47 a	6.79 a
	4 (S+CF)	32.9 ab	93.43 ab	9.78 a	10.70 a	8.21 c	20.6 a	23.94 b	5.36 b	11.52 a	6.77 ab
	5 (S+WF)	34.6 a	93.65 ab	9.49 a	10.28 a	9.13 a	21.9 a	25.56 ab	5.93 a	10.05 b	6.70 b
3 (strain Gurelan 45)	1 (S+SP)	35.5 abc	93.16 b	8.74 a	9.75 a	7.98 ab	20.4 a	23.50 a	4.74 b	11.42 ab	7.01 a
	2 (S+BP)	33.1 c	94.14 a	8.78 a	9.39 a	8.36 a	20.7 a	22.00 ab	5.31 a	11.27 ab	6.92 b
	3 (S+PB)	33.6 bc	93.64 ab	9.06 a	9.90 a	8.01 ab	20.2 a	21.23 b	4.96 ab	11.80 ab	6.95 ab
	4 (S+CF)	35.6 ab	93.94 ab	8.45 a	9.19 a	7.80 b	20.4 a	22.08 ab	4.80 b	11.93 a	6.99 ab
	5 (S+WF)	36.4 a	93.70 ab	8.76 a	9.57 a	8.20 ab	20.4 a	23.93 a	5.14 ab	11.15 b	6.98 ab

¹ Values followed by a different letter within a column and experiment are significantly different at 5% level according to Tukey's test. S+SP: soil + *sphagnum* blonde peat (4:1, v v⁻¹). S+PB: soil + composted pine bark (4:1, v v⁻¹). S+WF: soil + wood fibre (4:1, v v⁻¹). S+BP: soil + black peat (4:1, v v⁻¹). S+CF: soil + coconut fibre pith (4:1, v v⁻¹).

Table 2 shows the mean value of the qualitative production parameters for the three spawn types and five casing materials used.

In Experiment 1 there were no significant differences between the casings as regards carpophore diameter. In Experiments 2 and 3 there were significant differences in this respect between the wood fibre mixture and those containing black peat and composted pine bark; there were also significant differences in Experiment 3 between the coconut fibre and black peat mixtures.

The colour, particularly as far as luminosity is concerned, was better in the mushrooms produced under the black peat mixture, although any differences were only statistically significant between this mixture and the *sphagnum* peat mixture (in all three experiments) and, in Experiment 1, wood fibre. As regards the yellow-blue component, there were no significant differences between treatments in any of the experiments, while the differences in ΔE^* were only significant between the white and black peat mixtures.

The dry matter content differed considerably according to the strains used. In Experiment 1, for example, there were significant differences between the casing containing coconut fibre (high dry matter content of mushrooms) and those containing wood fibre and both kinds of peat. In Experiment 2 the wood fibre differed from the other casings as regards the dry matter content of the mushrooms, except from that containing black peat, which, in turn, also differed from the mixtures containing pine bark and coconut fibre. In Experiment 3, differences were only significant between black peat and coconut fibre.

As regards mushroom texture, no significant differences were observed between the mixtures in any of the experiments.

The protein content of mushrooms did not differ significantly between casings in Experiment 1 and only differed between coconut fibre and *sphagnum* peat in Experiment 2. In Experiment 3 the differences were between pine bark on the one hand and *sphagnum* blonde peat and wood fibre on the other.

The soluble solids (SS) also varied with the experiment in question. In Experiment 1, for example, the casing that included black peat provided the highest values, although without significant differences with respect to the values obtained with *sphagnum* peat and wood fibre. In Experiment 2, the mixtures containing black peat and wood fibre were responsible for the highest SS values, which differed significantly from the rest. In Experiment 3, black peat again produced the

mushrooms with the highest SS values, although significantly different only from the samples grown with *sphagnum* blonde peat and coconut fibre.

The ash content was highest with pine bark and coconut fibre in Experiment 1 although, in the case of the latter, without significant differences from the *sphagnum* blonde peat; in Experiment 2 the wood fibre mixture produced the lowest ash values, but without significant differences from the black peat; Experiment 3 produced significant differences only between coconut fibre and wood fibre.

The last parameter evaluated, pH, did not differ significantly between the casings used in Experiment 1 but did so between wood fibre on the one hand and pine bark and *sphagnum* peat on the other in Experiment 2. In Experiment 3 there were only significant differences between the two types of peat used.

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