# CONTRACT REPORT

# Exotic Mushroom Trials 2005-06

**Undertaken for**
**CENTRE FOR ALTERNATIVE LAND USE**
**under the**
**Farming Connect Scheme**

**Report To:**

Farming Connect Development Centre

Centre for Alternative Land use

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**AUTHENTICATION**

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

..... David Frost
Study Director

Date .....

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# Introduction

The market for edible mycorrhizal mushrooms has grown considerably in recent years and the market continues to grow due to interest in the nutritional and health benefits of edible mushrooms. The size of the market for speciality mushrooms has also increased and the overall market trend has been towards fresh rather than canned or processed product.

Mushrooms are extensively used throughout the catering industry, with high demand for fresh supplies in tourist areas especially during peak holiday periods. Although in terms of resident population Wales has a relatively small internal market for horticultural products such as mushrooms, the tourist market inflates demand considerably during the summer months. According to the Wales Tourist Board [1], total expenditure by tourists in Welsh rural areas is estimated to be £1 billion per year. As there is little existing mushroom production in Wales, there is considerable potential to supply the retail and catering/hospitality sector with local Welsh product.

The demand for organic mushrooms is also growing, but increased production is limited by the standards that require all straw and manure used in substrates to come from an organic source. Because of the shortage of organic straw, and its high price, organic growers need to examine alternative substrates.

*Speciality mushrooms*

Some commentators argue that there is a widespread fear of mushrooms and, further, that some cultures like the Anglo-Saxons are "mycophobic" whereas others, like the Slavic, prize mushrooms highly[2]. In the cusines of France, Germany, Italy and other continental countries a wide variety of edible fungi have traditionally been used. Many species are seasonally available with, for example, over 300 edible species licensed for sale in the fungi market in Munich. In the UK, by contrast, edible mushroom use has been largely confined to *Agaricus campestris* – the common field mushroom - and its cultivated form, *Agaricus bisporous.*

In the UK, there are however around 10,000 native species of fungi. Of these some 30 species are poisonous with 4 species potentially fatal, notably deathcap -*Amanita phaloides*. Among native edible varieties parasol,

[1] Wales Tourist Board (undated) *The size, characteristics and prospects for the farm tourism sector* Cardiff

[2] Daniel Butler (2006) "Lets put the fun back into fungi" Review of A. Letcher, *Shroom*, Faber 2006. *Guardian* 27.05.06 p 10

chanterelle, boletus, porcini, blewits and saffron milk caps are prized by fungi enthusiasts. Mabey (1972) provides a full list together with recipes[3].

With the rising interest in food and diet the interest in so-called exotic mushrooms has increased, fuelled by the drive for innovation and novel recipes among high-class restaurateurs and celebrity chefs. The use of oils derived from fungi for medicinal purposes has also developed, with the Welsh-based company Humungus Fungus specialising in shiitake oil following research by the proprietor, Richard Edwards, in Japan[4].

*Production of exotic mushrooms*

There are a number of different cultural methods in commercial use, with a wide variety of edible mushroom species produced on different substrates. The choice of species depends on the growth media available and on market considerations. The most common alternatives to *Agaricus bisporous,* which is traditionally grown on composted cereal straw and animal manure, include oyster mushroom, *Pleurotus spp*, which is produced on various growth media, and shiitake *Lentinus edodes,* which is grown on logs, sawdust or woodchip.

*Woodchip as an alternative to straw*

Straw has for long been the basis of livestock bedding but is becoming expensive, particularly in areas of the UK where it has to be imported. As a result, livestock farmers are becoming increasingly interested in alternatives. Initial observation studies at Pontbren suggested that hardwood chips offer considerable potential as bedding and that resultant composted manure may have a market potential.

*Background to the current study*

At ADAS Pwllpeiran, a study was undertaken in 2003/04 to investigate the potential of woodchip as an alternative to straw for animal bedding. Three bedding treatments were used; straw, hardwood chips and softwood chips for both a sheep and cattle study. Assessments were made for animals (performance, health, cleanliness and feed intake), bedding (quantity, frequency of bedding, costs and labour requirements) and the final compost (leachate losses, temperature changes during the composting process and the quality of the end product).

In a second ADAS study the resultant woodchip composts from the cattle and sheep bedding studies was used in a mushroom growing trial. Two approaches to growing mushrooms were evaluated - the establishment of an indoor growing room with mushrooms grown on trays and the establishment

[3] Richard Mabey (1972) *Food For Free – a guide to the edible wild plants of Britain,* London Collins. See Chapter 2 , “Fungi” pp 37- 59

[4] In Japan, shiitake and other fungi are eaten to avoid illness and as a prophylactic against cancer. Ironically, *Agaricus campestris* is regarded as carcinogenic in Japan. Richard Edwards *pers com*. 2004

of outdoor beds with or without weed suppressant matting. Four varieties of exotic mushrooms were evaluated including oyster, King stopharia, Agaricus blazei and parasol. Assessments comprised analysis of the nutrient level of the compost pre-inoculation and post-harvest, compost temperatures, mycelium growth, date of emergence of fruiting bodies, count of fruiting bodies, and weight of crop.

The preliminary results from this trial were that both indoor and outdoor systems resulted in mycelium growth, but fruiting bodies were only produced by oyster mushrooms. Generally the trial indicated that key issues for growing mushrooms on woodchip are,

1 The composition of substrate
2 Outdoor beds - raised beds or pits (pits became waterlogged during wet weather which inhibited delayed mycelium growth)
3 Indoor trays - casing layer

The objectives for the trials undertaken in 2005/06 for CALU under the Farming Connect programme were to continue the evaluation of outdoor woodchip beds but also to evaluate the use of raised beds. In this study further objectives were to evaluate alternative bedding materials (such as miscanthus, bark peelings, etc.) as a medium for growing culinary mushrooms and to evaluate systems to grow culinary mushrooms on inoculated wooden logs.

**Figure 1: Indoor growing system - oyster mushrooms fruiting on cattle hardwood compost, 30 January 2005**

# 1. ADAS Pwllpeiran Mushroom Trial 2005-06

## 1.1 Objectives

1. To continue the evaluation of outdoor woodchip beds constructed at Pwllpeiran in 2004.
2. To evaluate woodchip based compost in raised beds as a medium in the cultivation of culinary/medical mushrooms.
3. Evaluation of alternate bedding materials as a medium in the cultivation of culinary mushrooms.
4. Evaluation of different regimes in the growing of culinary mushrooms on inoculated wooden logs.

## 1.2 Materials

### 1.2.1 Composts used for raised beds

a. Mixed species hardwood chips used as bedding for finishing lambs on a farm participating in the Pontbren project.
b. Shredded wood bark (Various spa).
c. Shredded Miscanthus (M.sinsensis).
d. Shredded Giant Reed (*Arundo donax*).

### 1.2.3 Mushroom species trialed

*a)* Oyster *(Pleurotus ostreatus)*
*b)* Parasol *(Lepiota procera)*
*c)* King Stropharia *(Stropharia rugossa annulata)*
*d)* Morel *(Morchella esculenta)*
*e)* Cinnamon Cap *(Hypholoma capnoides)*
*f)* Wood Cauliflower *(Sparassis Crispa)*

The species identified were documented as growing on wood based substrates and would have a marketable value.

## Figure 2. Mushroom species documented as growing on wood-based substrates

**Cinnamon Cap**

**Cauliflower Mushroom**

**King Stropharia**

**Parasol**

**Morel**

**Oyster**

## 1.3 Methods

### 1.3.1 Inoculum production

1. Auto-claveable plastic bags containing organic wheat grain was sterilised at 135$^{o}$C (15psi) for 1 hour and left to cool under clean-room conditions for 30 minutes.
2. Segments of colonised agar of each culture were cut with a sterile scalpel within a laminar flow cupboard and placed into a labelled bag of grain.
3. The plastic bags were heat sealed and stored at 21$^{o}$C under natural lighting conditions until covered with mycelium.

### 1.3.2 Outdoor raised beds

During July 2005 two sets of raised beds were constructed from 5-6 inch diameter larch logs. The first bed was constructed in a shaded area in the National Botanic Gardens of Wales near Carmarthen. The second bed was constructed at Pwllpeiran adjacent to the woodchip plots set up in 2004.
At each site a 3 metre long, 0.6 metre wide and 0.4 metre high bed was constructed from 5-6 inch diameter freshly cut larch logs. Each bed was constructed over a 0.2 metre deep hole in the ground. The resultant bed was sub divided into four equally sized beds, each lined with Mypex to allow drainage and suppress weeds. Each bed was filled with Pontbren compost and inoculated with either Morel, Parasol, King Stropharia or Oyster mushroom spawn. The larch logs used for the construction of the raised beds were drilled and inoculated with Cinnamon cap or Cauliflower mushroom spawn. After the construction and inoculation of the raised bed had been completed at the Botanic Garden a temperature probe was installed into the core of the substrate to monitor temperature at hourly intervals.

**Figure 3 Raised beds at National Botanic Garden of Wales**

### 1.3.3 Drilled logs

At Pwllpeiran oak logs measuring approx. 4-5 inches in diameter and around 1 metre in length were drilled and inoculated with Miitake, Shiitake, or Hericium mushroom spawn. Larch logs of the same length and diameter as the oak logs were drilled and inoculated with Cinnamon Cap mushroom spawn. Six logs of each mushroom type were stored indoors in a shaded glasshouse, outdoors near the raised bed or buried below ground. The buried logs were situated in a bed dug some 10 inches deep and lined with Mypex and covered with 2 inches of beech woodchip. The logs were laid on the base layer of woodchip and then covered to ground level with beech woodchip.

### 1.3.4 Indoor Bottles and Bags

At Hummungus Fungus, near Llangadog, Carmarthenshire three types of possible alternative bedding material were evaluated under two different growing regimes. The alternate bedding materials evaluated were: -

Shredded wood bark *(Various spp).*
Shredded Miscanthus *(M.sinsensis).*
Shredded Giant Reed (*Arundo donax*).

Each material was evaluated as a growing medium for: -

| | |
|---|---|
| Cinnamon Cap | *Hypholoma capnoides* |
| Wood Cauliflower | *Sparassis Crispa* |
| Oyster | *Pleurotus ostreatus* |
| King Stropharia | *Stropharia rugosa annulata* |

This phase of the trial focussed on mushroom production from poly-bottles, a system developed in Japan for growing large volumes of edible mushrooms and poly-bags system used at Hummungus Fungus.

### 1.3.5 Poly-bottles

1-litre poly-bottles were hand filled to three-quarters of their capacity with each of the substrates. The partially filled bottles were sterilised at 135C (15psi) for 1 hour and left to cool under clean-room conditions for 30 minutes. After cooling the bottles were inoculated with grain spawn and sawdust-based spawn. Sterilised caps were fitted to the bottles, which were then placed on shelves in incubation laboratory and stored at 21$^{o}$C under natural lighting conditions to observe colonisation.

### 1.3.6 Poly-bags

Using results of mycelial colonisation of substrates from the poly-bottle trial, Oyster mushroom spawn was added to bags of Miscanthus and Giant Reed. Large autoclaveable poly-bags were hand filled to three-quarters of their capacity (2-3 kgs of substrate) with each of the substrates. The partially filled bags were sterilised at 135C (15psi) for 2 hour and left to cool under clean-room conditions for 1 hour. After cooling the bags were inoculated with

grain/sawdust-based spawn and heat sealed before storing at 21$^{o}$C under natural lighting conditions

### 1.4 Assessments

#### 1.4.1 Outdoor beds and logs

1. Weekly visual monitoring of surface mycelium and fruiting bodies.

#### 1.4.2 Indoor poly-bottles and bags

2. Weekly visual monitoring of mycelial growth and fruiting bodies by Hummungus fungus staff.
3. Regular visual monitoring of surface mycelium and fruiting bodies by ADAS staff.

### 1.5 Results

#### 1.5.1 Outdoor Beds

No further fruiting of inoculated mushrooms species occurred during 2005 or early 2006. Regular assessments detected mycelial growth on a number of plots during mid July, and a large number of Cortinariaceae mushrooms (probably from the group Gallerina or Tubaria) fruited shortly afterwards. Cortinariaceae is a very large family with some of its members living on wood, while others are terrestrial or from the ground. The edibility of Cortinariaceae mushrooms is unknown.

#### 1.5.2 Outdoor Raised Beds

By early winter 2005 evidence of mycelial growth was detected on the cut ends of the drilled log structure at both sites. However no mushroom fruiting has occurred from either inoculated mushroom species on the drilled log structure. At both Pwllpeiran and Botanic Garden sites most of the inoculated mushroom species had spread into their surrounding substrate by late autumn, with the Oyster mushroom mycelium spreading the most. During early February 2006 oyster mushrooms fruited in their inoculated bed at Pwllpeiran, this has not been replicated at the Botanic Gardens. The yield of Oysters mushroom fruit was not taken as they were used as an exhibit during an open day “Woodchip as alternate bedding” in mid February 2006

#### 1.5.3 Logs

Close inspection of the cut ends of both the indoor and outdoor logs detected evidence of mycelial growth by early December 2005. Logs buried in hardwood chips have been left covered and undisturbed to avoid any possible damage to protruding fruiting bodies. Thus the extent of any possible mycelial growth is not known. Although evidence of mycelial growth has been seen no fruiting has occurred.

**With several very cold periods over the 2005/06 winter it is possible that fruiting may occur in the beds and logs when temperatures rise in spring 2006.**

### 1.5.4 Indoor Poly-bottles

Mycelium spread quickly from inoculated spawn into all substrates, with mycelium visible 2 weeks after inoculation. By 6 weeks after inoculation Oyster mycelium covered 100% of the surface of all substrates, and King Stropharia covering approximately 20%. Cauliflower and Cinnamon Cap mycelium covered about 10% and 4% respectively. Assessments carried out during 10 weeks after inoculation showed an increase in mycelial growth and a differentiation between substrates.

**Table 1. Extent of substrate covered by mycelium of each species, 10 weeks after inoculation**

| | Cauliflower | King Stropharia | Cinnamon Cap |
|---|---|---|---|
| Miscanthus | 25% | 60% | 60% |
| Giant Reed | 10% | 30% | 50% |
| Bark peelings | 5% | 25% | 5% |

By week 10 Oyster mushroom fruited on Miscanthus and Giant Reed substrates. Although the bark peelings were 100% covered in mycelium no fruiting had occurred by week 10. No yield measurements were taken as the fruiting mushrooms were used as an exhibit on the CALU stand at the 2005 Winter Fair held at Builth Wells.

By week 10 the Pontbren woodchip substrates were contaminated by Pin Moulds and had to be removed before possibly contaminating other bottles. Continuing regular assessments showed increased levels of colonisation in all substrates until week 26.

No other mushrooms fruited on any substrate.

### 1.5.5 Indoor Poly-bags

Several bags of both Miscanthus and Giant Reed were inoculated and rapid colonisation of both substrates occurred. Colonisation continually increased reaching 100% by week 10 after inoculation. The upper section of bags was removed during week 12 after inoculation and the substrate moved into a growing room at fluctuating temperatures between 12-20C and humidity set to fluctuate between 75-95%. Fruiting occurred on both substrates during week 14 with Giant Reed yielding 104g of Oyster mushrooms and 68g from Miscanthus.

## 1.6 Conclusions

A varying degree of mycelial growth was found on each of the substrates and for each of the varieties. The only variety to fruit was oyster mushroom which fruited on the woodchip substrate on the outdoor raised beds, on the Miscanthus and Giant Reed Grass substrates in the indoor poly bottles and on the Miscanthus and Giant Reed Grass substrates the indoor poly bags.

These results parallel those of the 2004 trials and it has to be concluded that the commercial possibilities of cultivating varieties of edible fungi on woodchip-based and other substrates has yet to be demonstrated.

Although considerable information and experience has been gained in these trials the large number of variables involved – type of substrate, species of fungi, indoor or outdoor system, weather and climatic conditions, pests and diseases – merit further investigation. It is also the case that the time-scale necessary for the study of the potential of these species and substrates is much longer than has been available in these trials.

The history of the successful development of a mushroom growing sector in Ireland indicates the need for long-term development. The use of synthetic composts rather than horse manure for mushroom production – first developed at the Kinsealy Research Centre – were only introduced commercially in the 1970s. Further, although the use of plastic bags for mushroom cultivation first arose from work at the Danish Mushroom Research Station in 1960/61 it was only after further trials at Kinseally in 1970 that this system became widely used.[5]

At present the potential for outdoor exotic mushroom growing in Wales is likely to be limited to small-scale growing of oyster mushrooms or shiitake on oak logs. These systems can provide additional on-farm enterprises for farms wishing to diversify and to supply local markets, but harvest period and yield is likely to be erratic and dependent on weather and seasonal conditions. Indoor production in controlled environmental conditions offers more commercial potential and franchise possibilities exist to grow shiitake for oil production using a sawdust & woodchip-based substrate.

The development of exotic mushroom production in Wales would require further research and development, with a high level of resource provision as available in the Irish programme at Kinseally described above. Suitable analytical laboratories would also be required. Currently fungi samples and extracts are sent to California for analysis, as no suitable laboratories are available in the UK[6].

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[5] C MacCanna (1974) “Mushrooms in Plastic Houses” in *Crop Production under Plastic.* An Foras Taluntais, Kinsealy Research Centre, Malahide Road, Dublin 5.

[6] Richard Edwards (2004), pers.comm

## 1.7 Knowledge Transfer undertaken during the project

1. Poster – Exotic mushroom growing, displayed on the ADAS stand at the Winter Fair 2004.

2. Poster - Exotic mushroom growing, displayed on the CALU stand at the Royal Welsh Show 2005

3. Poster - Exotic mushroom growing, displayed in the learning section at the Botanic Garden of Wales main glasshouse during spring-autumn 2005.

4. Power Point presentation "The multi-use of woodchip - from livestock bedding to mushroom production" *Ecosystem of farm trees* Farm Woodland Forum Annual Conference 29 June – 1st July, University of Wales Conference Centre Gregynog, Powys, Wales

5. Poster - Exotic mushroom growing, displayed on the CALU stand at the Winter Fair 2005.

6. Permanent display board at the Botanic Garden of Wales covering aspects of woodchip based compost used in the raised bed.

7. Poster - Exotic mushroom growing, displayed at ADAS open day February 2006.

Appendix 1.

**Analysis of wood chip compost**

| | | |
|---|---|---|
| pH | 7.9 | |
| Conductivity | 445 | µS@20$^{o}$C |
| Density | 486 | g/l |
| Phosphorus | 119 | mg/l |
| Potassium | 526 | mg/l |
| Magnesium | 39 | mg/l |
| Mineral Nitrogen | 126 | mg/l |
| Nitrate as N | 125 | mg/l |
| Ammonia as N | 1 | mg/l |
| Calcium | 61 | mg/l |
| Sodium | 201 | mg/l |
| Chloride | 160 | mg/l |
| Sulphur | 41 | mg/l |
| Boron | 0.32 | mg/l |
| Copper | <0.15 | mg/l |
| Manganese | <0.1 | mg/l |
| Zinc | 0.50 | mg/l |
| Iron | 0.79 | mg/l |

# Appendix II:Plot Layout

| | | |
|---|---|---|
| Sheep Hardwood | Oyster | Uncovered |
| Sheep Hardwood | Oyster | Covered |
| Sheep Softwood | Oyster | Uncovered |
| Sheep Softwood | Oyster | Covered |
| Cattle Softwood | Parasol | Uncovered |
| Cattle Softwood | Parasol | Covered |
| Sheep Softwood | Parasol | Uncovered |
| Sheep Softwood | Parasol | Covered |
| Sheep Hardwood | Agaricus blazei | Covered |
| Sheep Hardwood | Agaricus blazei | Uncovered |
| Sheep Softwood | King stropharia | Covered |
| Sheep Softwood | King stropharia | Uncovered |
| Cattle Softwood | King stropharia | Uncovered |
| Cattle Softwood | King stropharia | Covered |
| Cattle Softwood | Agaricus blazei | Uncovered |
| Cattle Softwood | Agaricus blazei | Covered |
| Cattle Hardwood | Parasol | Uncovered |
| Cattle Hardwood | Parasol | Covered |
| Cattle Hardwood | Agaricus blazei | Covered |
| Cattle Hardwood | Agaricus blazei | Uncovered |
| Cattle Softwood | Oyster | Covered |
| Cattle Softwood | Oyster | Uncovered |
| Sheep Hardwood | King stropharia | Covered |
| Sheep Hardwood | King stropharia | Uncovered |
| Sheep Softwood | Agaricus blazei | Uncovered |
| Sheep Softwood | Agaricus blazei | Covered |
| Sheep Hardwood | Parasol | Uncovered |
| Sheep Hardwood | Parasol | Covered |
| Cattle Hardwood | Oyster | Uncovered |
| Cattle Hardwood | Oyster | Covered |
| Cattle Hardwood | King stropharia | Covered |
| Cattle Hardwood | King stropharia | Uncovered |
| Cattle Softwood | **Guard plot** | Covered |
| Cattle Softwood | **Guard plot** | Uncovered |

Appendix III : Raised bed Temperature