HGCA

PROJECT REPORT No. OS23

USE OF INDUSTRIAL RAPESEED MEAL FOR SUPPLEMENTATION OF MUSHROOM COMPOST

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by

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Contents

1. SUMMARY

- This report outlines research undertaken at SAC Auchincruive on behalf of the Home-Grown Cereals Authority (HGCA) to study the potential for using rapeseed meal (RSM) for the supplementation of mushroom compost.

- Mushrooms (*Agaricus bisporus)* require to be grown on substrate which has a particular availability of nutrients in balance with a microbial population which both contributes to nutrient availability and provides a biochemical 'trigger' for production of edible mushrooms from the otherwise filamentous culture of mushroom hyphae.

- The crop is typically grown on a composted blend of manures and straw supplemented with a range of materials to balance nitrogen / carbon ratios and to adjust texture and pH.

- This project investigated whether RSM may serve such a purpose. This was achieved by supplementing proprietary compost and producing the crop under small-scale commercial conditions.

- RSM failed to enhance mushroom yields in the test crop. However, biological activity of the crop, as measured by temperature profile in compost, was significantly greater than in untreated controls.

- Incubation of test material together with cultures of mushroom mycelium indicated that supplied material exhibits a level of fungitoxicity against *A. bisporus*.

- These incubation test were carried-out following conventional autoclaving of test material. Surprisingly, this procedure did not achieve sterilisation / disinfection. A proportion of cultures were contaminated by fungi and bacteria which were believed to originate from the RSM.

- This indicated that while the test material appears unsuitable for mushroom supplementation it may have other potential biological applications.

- RSM was incorporated as an additive to an unreplicated sample of material due for recycling by composting. This was included as a batch of material in a programme of work to study other parameters of composting science.

- This batch of compost performed well in comparison to previous samples. However, firm conclusions should only be based on replicated trials which are outwith the scope of this report.

- Success in supplementation of composts such as recycled green (botanical) waste or industrial composting may provide opportunities for marketing of RSM as a compost activator. The market for this type of product is rapidly expanding although trends in the sector are difficult to predict.

- Recommendations are made to further determine the potential for a product of this type.

2. INTRODUCTION

One of the consequences of an increase in the use of oil-seeds is the wide availability of the primary material and also the waste products from subsequent processing. To improve the economics of these crops alternative uses for by-products are sought. In order to achieve this, market opportunities must be identified and tested. One such possible combination is the use of oilseed rapemeal for supplementation of compost used for the production of mushrooms.

The mushroom industry is the largest protected-crop sector in UK horticulture. Annual turnover is in excess of £160 million *per annum*. Although a wide range of mushroom species are recognised as edible, European production is almost exclusively of one species, *Agaricus bisporus*. The production cycle is complex and is summarised as an appendix to this report.

Compost is produced from a range of raw materials, i.e. chicken manure, straw and a small range of additives. The quality of such raw materials can vary from season to season. Compost producers use a range of supplements to improve the nutrition of composts. Chemical fertilisers are not used as supplements because the mushroom crop and the associated microflora which enact the composting process rely on organic carbon and nitrogen sources. The release pattern from artificial fertilisers is usually unsatisfactory for supporting microbial growth.

This project investigated whether rapeseed meal (RSM) can be advantageously used to supplement mushroom compost. However, some glucosinolates may be toxic to fungi. It was considered necessary to test material for toxicity to *A. bisporus* in order to determine the extent of opportunities for product development.

The main objectives were:

- To interpret the nature of proposed materials in regard to suitability for use in the mushroom industry.

- To determine toxicity of materials against the mushroom crop (*A. bisporus*).

- To test on a pilot scale the supplementation of mushroom composts at spawning of a crop.

- To state business opportunities for exploitation of test material and to state developments necessary to secure these.

3. MATERIALS AND METHODS

3.1 Mushroom production

Mushrooms were produced under standard commercial conditions in a controlled-environment growing room. This was equipped with microprocessor controlled heating and cooling with facility for fresh air input as required by the crop. Approximate cultivation requirements details are given in Appendix 1 and readers are referred to specific texts on mushroom cultivation (Appendix 2).

Compost was supplied by McGeary Mushroom Compost Ltd. (Armagh, N.I.) and was a standard commercial mix of straw, deep litter poultry manure and gypsum with a proportion of horse bedding. Supplementation of compost with RSM was by hand on delivery, that is at the point immediately following spawning (inoculation) of *A. bisporus* (Strain: Le Champignon 130) to the compost. Bags of compost were individually weighed prior to the addition of RSM. Unsupplemented controls were handled in the same manner without addition of RSM. The rate of incorporation assumed an organic-N source of lysine of approximately 2%. A range of rates was then selected to approximate typical incorporation of proprietary mushroom compost supplements. Rates are as shown in Table 3.1.1.

Table 3.1.1: Treatment codes for mushroom production

TREATMENT	TYPE	% INCORPORATION (Fresh weight)
1	Control 1	0.0
2	Grain (A)	0.6
3	Grain (A)	1.2
4	Grain (A)	1.8
5	Lump (B)	0.6
6	Lump (B)	1.2
7	Control 2	0.0

Bags of compost were placed directly on the floor of the growing room in a balanced randomised block design with seven blocks, each containing bags of the seven treatments (Day 0). As per normal practice, environmental control was initially adjusted according to bag temperature, not air temperature. In some cases temperature of bags exceeded guidelines, suggesting a relatively high metabolic activity in some treatments. Bag temperature was controlled by adjusting heating/cooling in the growing room. Principally, temperature in supplemented bags was higher than in untreated controls. Because of the risk of overheating, resulting in damage to the crop-fungus, temperature was largely controlled **to favour** those treatments containing high levels of RSM.

After initial incubation and at a point where the majority of bags were fully colonised by *A. bisporus*, each was covered with a layer of peat 'casing' (Day 19). This pH adjusted material was a proprietary peat-mix supplied by Country Mushrooms Ltd. (Kilmarnock). The purpose of this secondary layer is to provide the correct environmental, nutritional and biological conditions for initiation of mushrooms. In the early stages of growth after casing control remained on the basis of bag temperature. Latterly from the point of initiation of mushrooms (Day 31) environment control was aimed at providing correct atmospheric conditions, particularly carbon dioxide concentration (measured by use of detection tubes Gastec Ltd/ Detection Instruments Ltd , Irvine) and air temperature.

Pesticide use was minimised to better demonstrate the different pest and disease incidence, if any, between treatments. Application of the fungicide Prochloraz

manganese (Sporgon 50WP) was however carried out at casing, according to label recommendations, to minimise potential infection by major pathogens, particularly *Verticillium fungicola* and *Mycogone perniciosa*.

Mushrooms were harvested at the point of veil break, i.e. at mature button / cup stage from Day 40. Harvesting was carried out daily with major 'flushes' occurring at approximately weekly intervals for four weeks.

Numbers, weight and quality of mushrooms were recorded for each bag. Records of the incidence of pest and disease were also made.

3.2 Fungitoxicity

Samples of RSM were tested for toxicity to the crop fungus *A. bisporus* under laboratory conditions. Cultures were established of *A. bisporus* strain used for cropping trials by isolating samples of tissue from mature fresh sporophores (mushrooms) under axenic conditions and plating these onto agar containing 100μg cm^{-3} streptomycin sulphate (Sigma). *A. bisporus* was placed off-centre on either malt or Czapek Dox agar in 9cm petri dishes.

Samples of the two types of RSM were then subjected to sterilisation treatment of autoclaving under standard conditions of 120°C @ 1 bar pressure for 15 minutes in a closed vessel. RSM sub-samples of approximately 0.5ml were then each placed in proximity to cultures of *A. bisporus*, as previously prepared. Controls of *A. bisporus* cultures in the absence of RSM were also established. Plates were incubated at 24°C ±1°C until control cultures were close to the edge of the culture dish, after approximately 21 days.

Growth of *A. bisporus* both towards and away from RSM was measured and compared to growth of controls. Records were also taken of the level of sample contamination.

3.3 Composting

In a separate programme of work to investigate the role of minerals in composts there was a requirement for a blend of compostable material at the same time as the reported programme of work was undertaken. RSM was included in spent mushroom substrates (SMS) which were the principal component of the recycling programme. Typically SMS re-composts reasonably well but generally fails to reach target pasteurisation temperatures due to an imbalance of carbon : nitrogen in the unadjusted material. For this part of the programme blended RSM was incorporated to an estimated rate of 0.5% fresh weight. However, this was outwith the remit of the agreed study and was not carried out as part of a replicated trials programme.

4. RESULTS AND DISCUSSION

4.1 Mushroom production

Temperature profile pre-cropping

Temperature of compost in cropping bags was recorded daily. These data are shown graphically in Figure 4.1.1. Bags containing RSM achieved highest temperatures with Treatment 4 exceeding guidelines (>30°C by day 6). All treatments containing RSM exceeded this figure at some point during incubation despite constant operation of the cooling system. Typically *A. bisporus* may survive at temperatures up to c.34°C with higher temperatures likely to be lethal to the fungus. Figures of this order were recorded for samples in treatments two to six, i.e. for all RSM containing treatments. Maximum recorded temperature was 36.2°C in one bag of Treatment 5 on day 12.

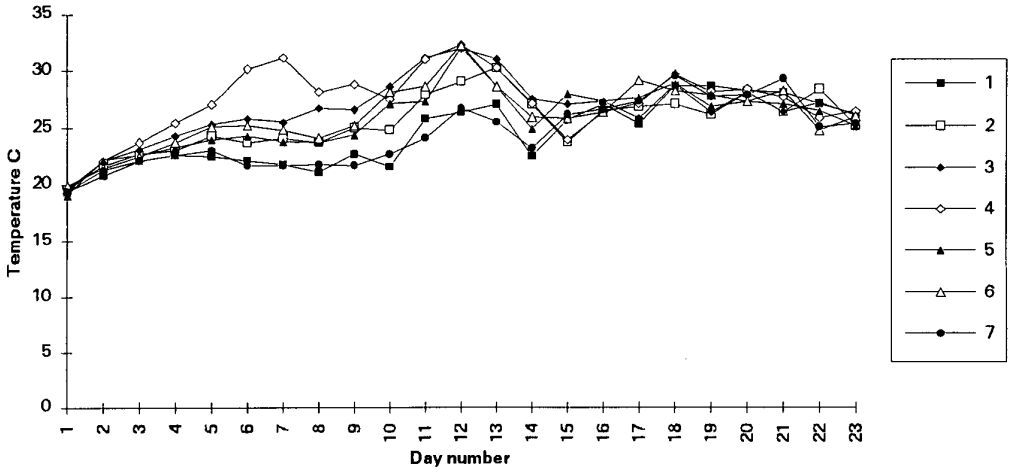

Figure 4.1.1: Average temperature profile in compost pre-cropping

Key designates Treatment code as per Table 3.1.1

Yield of mushrooms

Yield of mushrooms was recorded on a daily basis. Harvesting was by normal commercial practice of removing mushrooms from the growing layer and trimming stalks at the base, above the level of the casing. Yields were significantly lower in plots supplemented with RSM compared to controls ($p<0.001$). Position of cropping bag also had a significant effect on harvestable yield ($p<0.01$). Analysis of data is summarised in Table 4.1.1 and presented in detail in Appendix 4.

Table 4.1.1: Summary data of accumulated yield of harvestable mushrooms with and without RSM (kg).
Treatment codes are as per Table 3.1.1

Treatment	Type	Yield
1	Control 1	65.66
2	Grain (A)	23.26
3	Grain (A)	24.78
4	Grain (A)	19.2
5	Lump (B)	36.8
6	Lump (B)	21.1
7	Control 2	67.68

Variation between bags in any one treatment was large (Figure 4.1.2.). The relationship between maximum temperature reached in bags of compost during incubation, pre-cropping and yield of mushrooms for all treatments is shown in Figure 4.1.3. The high degree of scatter indicates that yield is not simply related to incubation condition and that some other factor such as toxicity of RSM to *A. bisporus* may be relevant.

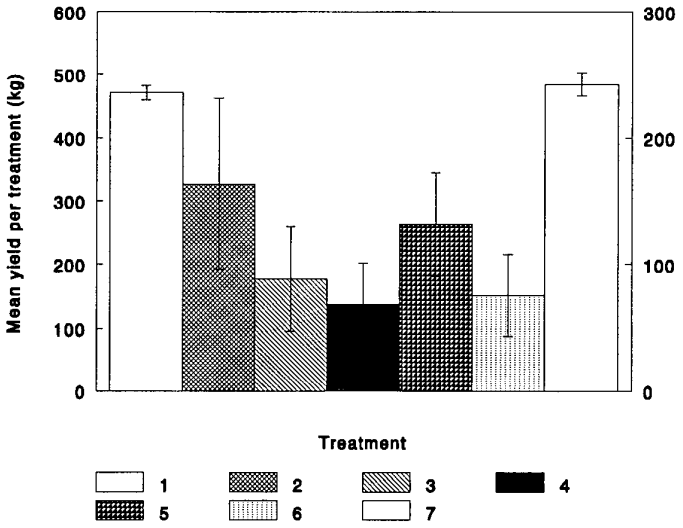

Figure 4.1.2: Comparative yield of mushrooms per treatment

Key designates Treatment code as per Table 3.1.1

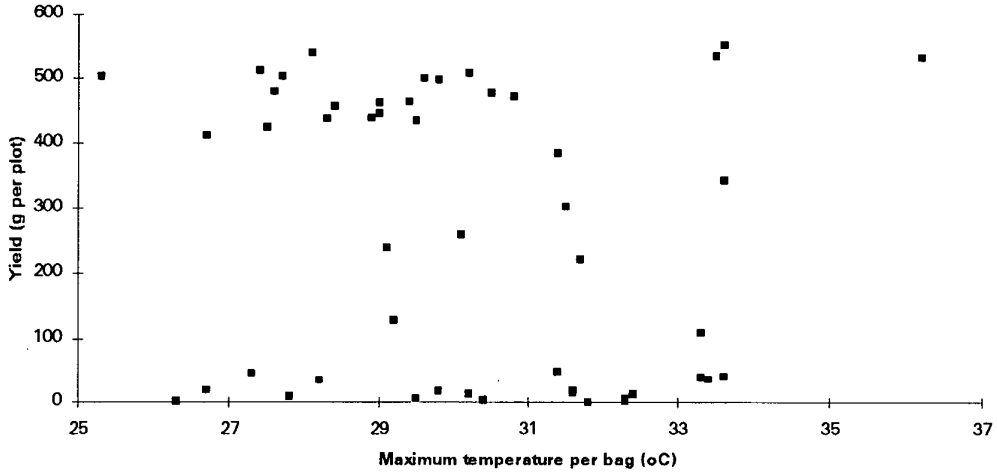

Figure 4.1.3: Relationship between maximum bag temperature and yield for all treatments

Pest and disease incidence

The principal disease recorded was *Trichoderma* spp. This fungus invades both compost and casing and causes loss by competition for nutrients and surface area, so reducing cropping. Appearance is not uncommon in commerce and is principally related to overheating of compost during incubation, a procedure which is believed to favour germination of resting spores. Dispersal of spores of the pathogen was minimised by application of common salt to infected areas to dehydrate the mycelium. Levels of infection were as shown in figure 4.1.4. Infection by *Botrytis* spp. was also recorded towards the end of cropping, principally on treatment 6, but also on treatments 2, 3 and 5. The level of infection was however incidental compared to the severity of *Trichoderma* spp.

Towards the end of cropping phorid and sciarid flies became a problem. This is quite normal in the absence of pest control and did not appear associated with particular treatments.

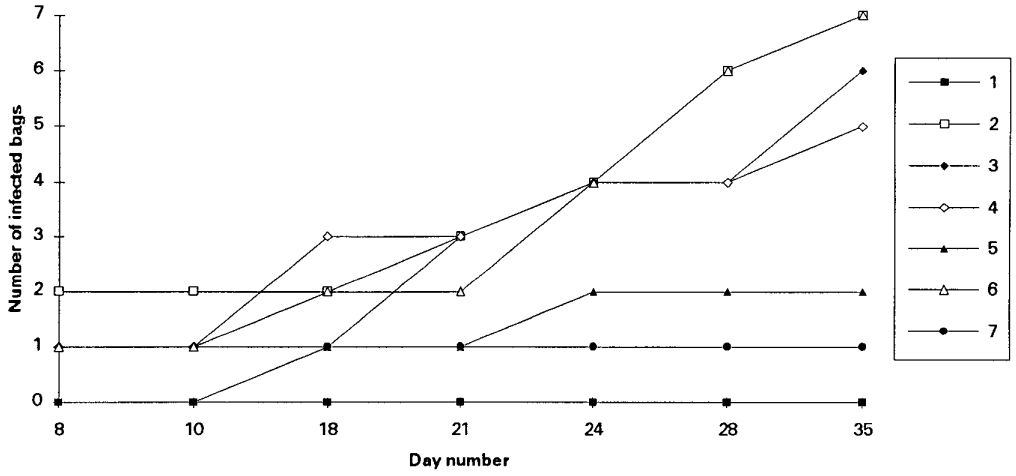

Figure 4.1.4: Number of bags infected with *Trichoderma* spp.

Key represents treatment code as per Table 3.1.1

4.2 Fungitoxicity

Overall, under laboratory conditions growth of *A. bisporus* in the presence of RSM was significantly reduced compared to controls ($p<0.09$ **). Growth in the presence of the grain formulation A was on average 83.9% of controls and was 87.5% in the presence of lump material, formulation B. Growth in culture towards RSM was reduced the most (49.1% of controls for RSM grain formula A compared to 62.1% for RSM lump formula B) ($p<0.09$ **). Away from RSM growth of *A. bisporus* was reduced to a lesser extent ($p<0.2$ *) at 67.5% and 78.4% of controls for formulae A and B respectively.

These data indicate that both RSM formulations are potentially inhibitory to the crop fungus *A. bisporus* and that inhibition is due to a diffusible component, rather than a volatile emission. Were the latter true, inhibition would have been uniform across cultures rather than at the side nearest RSM, as observed. These data are shown more fully in Appendix 4.

Contamination was noted in a number of cultures containing RSM while control cultures of *A. bisporus* alone remained unaffected. This was primarily of fungi (38.7%) although some bacterial contamination was also noted (15.8%). Contamination in each case was centred on the RSM samples. This indicated a failure of autoclaving to satisfactorily sterilise RSM. This was considered surprising in view of the grain and relatively small lump size (c.1cm) of the two types of test material.

A range of contaminating species types were observed in culture but identification was **not** within the remit of this study. However, it was apparent that *Trichoderma* spp. were **not** noted in culture. In the presence of contaminating organisms inhibition of *A. bisporus* was considerable. The exact role of contaminants resident in RSM was not fully elucidated. However, there is sufficient evidence to suggest that material is difficult to disinfect and that this is necessary for use in association with *A. bisporus*.

Overall, inhibition of *A. bisporus* appears to be due to a combination of chemical, diffusible, components of RSM in combination with resident fungal and/or bacterial contaminants that may also be inhibitory.

4.3 Composting

Incorporation of RSM into SMS for recycling was carried out in controlled environment chambers. Pasteurisation of all four samples was good, reaching target temperature of 58°C on day four (Figure 4.3.1). Such temperatures are required for varying lengths of time depending on the inherent disease risks associated with material for recycling. Used mushroom compost rarely may achieve pasteurisation without supplementation because of the relatively low metabolic activity post-cropping. These data are therefore encouraging for the potential use of RSM as a general compost supplement rather than as one specifically targeted at the mushroom sector. Temperature attainment is particularly important where human or animal pathogens may be present such as in composted manures or sewage sludge.

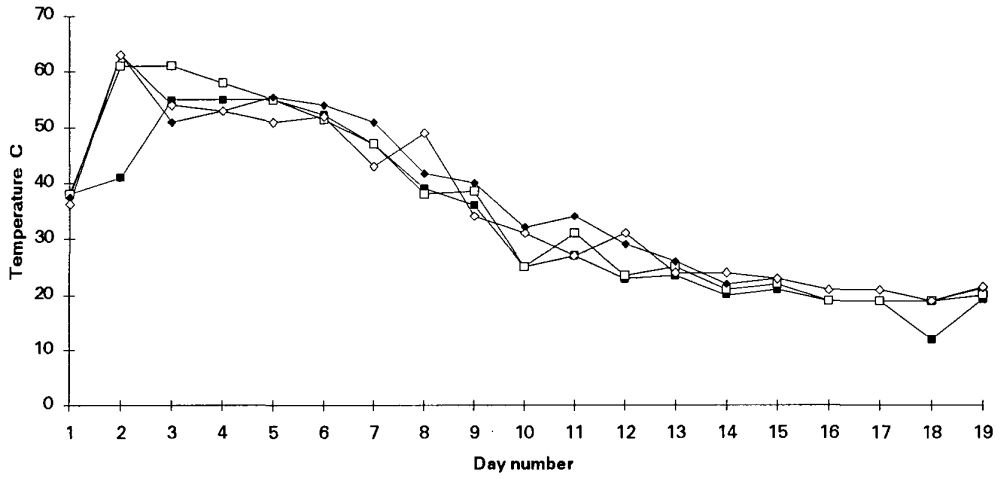

Figure 4.3.1: Temperature profile for recycled SMS containing RSM

The indication that incorporation of RSM was a significant factor in raising metabolic activity and therefore temperature in the main trial of mushroom production is supported by these data. However, it is important to note that this element of the work is preliminary and requires to be replicated.

5. CONCLUSIONS

This report outlines research undertaken at SAC, Auchincruive to study the potential for using rapeseed meal for the supplementation of mushroom compost.

The mushroom crop is typically grown on a composted blend of manures and straw supplemented with a range of materials to balance nitrogen / carbon ratios and to adjust texture and pH. This project investigated whether RSM may serve such a purpose. This was achieved by supplementing proprietary compost and producing the crop under small-scale commercial conditions.

RSM failed to enhance mushroom yields in the test crop. However, biological activity of the crop, as measured by temperature profile in compost, was significantly greater than in untreated controls. The correlation between temperatures in cropping bags during incubation and subsequent yield was not good, indicating that this alone was not the principal reason for poor yield in the presence of RSM. A possible explanation for this was shown in incubation tests of cultures of *A. bisporus* in the presence of RSM. Inhibition of the crop-fungus by RSM may account for poor yields and this is a clear indication of the unsuitability of the use of RSM for mushrooms. In addition, incubation test were carried-out following conventional autoclaving of test material. Surprisingly, this procedure did not achieve sterilisation / disinfection. A high proportion of cultures were contaminated by both fungi and bacteria which were believed to originate from RSM. This indicated that while the test material appears unsuitable for mushroom supplementation it may have other potential biological applications.

RSM was incorporated as an additive to an unreplicated sample of material due for recycling by composting. This was included as a batch of material in a programme of work to study other parameters of composting science. This batch of compost performed well in comparison to other materials. However, firm conclusions should be based on replicated trials which are outwith the scope of this report.

6. RECOMMENDATIONS FOR FURTHER WORK

Continuation of a programme to study the incorporation of RSM into mushroom compost is not recommended. This is with the *caveat* that development in formulation, particularly with regard to control of potential microbial contamination of material, may warrant reconsideration.

The principal opportunity for use of RSM demonstrated in this work is as an enhancer of compost development, not for mushroom production, but for other non-crop processes. Examples where this may apply include the material used in this study, recycled SMS and other organic / green (botanical) wastes. Previous work carried out at SAC, Auchincruive has included recycling of woodwastes, industrial wastes such as seaweed residues and poultry manures. The target markets for composted material lie in the production of peat-substitutes for use in horticulture and waste reduction by composting prior to application to soil or to land-fill. The principal parameters of acceptable hygiene and volume reduction are typically more achievable if composting processes are guaranteed to reach pasteurisation temperature by thermophilic (high temperature) microbial activity.

A related market opportunity lies in domestic composting by sale of proprietary activators. This is an expanding opportunity as a number of local authorities are examining the possibility of encouraging home composting - so removing biodegradable materials from the domestic waste-stream. A number of pilot scale projects are currently in operation and may be expanded.

The market for composted materials for purposes other than mushrooms is difficult to predict. However the current market position of peat, for which such material may substitute, is approximately 1 million wet tonnes per year in the UK alone. At a rate of incorporation of 0.5% fresh weight into an equivalent composted product this would present a market opportunity of approximately 5000 tonnes per annum. With regard to the need to accelerate waste reduction, as opposed to composting to produce specific products, the EU Urban Waste Water Directive, effective from 1998 demands an increase in land-based organic waste disposal to an as yet undetermined extent. Preliminary estimates indicate that biosolid production from urban waste water

treatment will increase seven-fold. This material will have to be reduced in volume in a hygienic manner and used in as yet unspecified ways. There is a clear potential for enhancing composting of such material using activators such as RSM in the composting formula.

This aspect of composting is not targeted at specific crops but may result in composts for application to landscape and land-renewal projects. As such it would fall outwith the scope of the Blair House Agreement, offering a new potential market.

APPENDICES

Appendix 1: Mushroom Production Summary

Reproduced from:
Horticulture and Plant Biotechnology in Scotland

Mushroom cultivation:
Biotechnology in practice

Production of mushrooms in the UK is, almost without exception, concerned with cultivation of one species, *Agaricus bisporus*. Fossil records show that mushrooms have existed since at least the Tertiary Era. However, mushroom growing, as opposed to picking of fruiting bodies appearing in the wild, first started in France only around 1650.

From crude beginnings there are now sophisticated cultivation systems, including compost production and industrial inoculants for specific selections, or strains, of mushroom. Today the cultivation of mushrooms is a multi-faceted process encompassing as much sophisticated biotechnology as any industrial process.

BIOLOGY OF MUSHROOMS

In nature, mushrooms appear relatively infrequently. Only when the nutritional and environmental conditions are right do fungi which can produce mushrooms do so.

Mushrooms that are sold in supermarkets or from baskets in corner shops are only the 'fruiting body' of the fungus (*A. bisporus*) which produces them. They are not the entire fungus and have relied on a network of filamentous strands (fungal hyphae) to reach this stage of maturity. The cultivation of hyphae and the way in which nutrition and environments are manipulated to force a change from vegetative to reproductive growth to produce mushrooms for harvesting is the key to success in crop production.

To achieve success we have to understand the natural cycle of degradation which contributes to fungal nutrition and understand the way that we can manipulate this. In nature, leaf litter and plant debris are degraded by a sequence of organisms, returning organic matter for use through the carbon cycle. One such 'link in the chain' are the *Basidiomycete* fungi such as the cultivated mushroom. As a general rule the success of any soil inhabiting fungus is dependent on the biological activity and residues left by those which precede it. Similarly other fungi, bacteria and insects are ever-present in the wild to continue the degradation cycle from high fungi. Cultivation of mushrooms is designed to maximise the benefit of organisms occurring naturally in composting processes and to minimise incursion of other organisms that would continue the degradation cycle and spoil the high quality crops that are the growers' target. In the autumn, before mushrooms naturally appear, falling of leaves and senescence of field herbage provides a change in the physical environment. This supply of organic material which has yet to significantly break down is also important in changing the microclimate and biological status of the soil surface. These changes contribute to changes in the reproductive growth of fungi and have to be copied in mushroom crop production.

Mushroom cultivation can be viewed, in biological terms in two ways. Firstly the manufacture of composts and management of growing environments is a way of encouraging natural biological control of undesirable organisms that would otherwise prevent successful cultivation of the crop. Secondly the grower is trying to reach the 'window of opportunity' for the environmental conditions that the crop needs. In nature this would only occur once a year, and the aim of cultivation is to hold it open for year round production.

THE COMPOSTING PROCESS

Mushroom compost was traditionally based on horse manure and a mix of other ingredients, particularly straw. Early research showed that to eliminate potentially harmful fungi, bacteria and pests material had to be pasteurised. Today most growers use compost with little or no horse manure, reducing the unpredictability of the substrate, and mostly use instead chicken-litter, straw and gypsum. This is then processed in a multi-stage composting procedure. After rough mixing of materials Phase I composting begins. In this Phase materials are stacked and watered to soften the straw and make it susceptible to degradation. Material is stacked by machine and aerated by turning or forced-air ventilation to produce a partially degraded and biologically active material. This is then transferred to specially designed rooms or 'tunnels' with sophisticated environmental control for Phase II. The compost is next allowed to heat to a high enough temperature for pasteurisation to occur, usually around 58-60°C for up to twelve hours. Further biological processes are controlled at a lower temperature of around 48-53°C for about 7 days for the compost to become 'conditioned'. This period is one of intense microbial activity and leaves a compost with a nutritional and microbiological balance which is ideal for the growth of the crop fungus.

SPAWN

In the early days of mushroom cultivation spawning was by transferring compost from an old crop to a new one. This carried great risk of spreading diseases and pests to the new crop and yields were correspondingly below potential.

Today *A. bisporus* is introduced to the compost as a culture produced by a small number of highly specialised biotechnology companies. Most such companies provide spawn as a fungal culture of *A. bisporus* which has fully colonised sterilised-grain. This gives an easily handled spawn which can be readily broken into granules for distribution throughout the compost. Manufacture of spawn is carried out under strict conditions of hygiene and is always separate from crop production. Many spawn companies also have their own research, mushroom breeding and selection programmes.

CROPPING

Inoculated compost is incubated within insulated buildings equipped with environmental control. A modern mushroom farm with insulated houses is generally designed to blend in with the surrounding countryside and is often not even noticed by passers-by!

Within the growing environment compost is incubated to maximise the rate at which *A. bisporus* colonises the compost. Temperatures of about 26°C are used and raised carbon dioxide levels are produced by fungal metabolism. These conditions encourage the filamentous fungi to colonise the compost. The fungus relies not only on chemical nutrition of the compost but also, by using an armoury of enzymes, on the biological nutrition of bacteria which were previously responsible for the composting process.

When the compost has been fully colonised an extra layer, usually of peat, is added to the surface. This so called 'casing' layer mimics the function of an autumn leaf-fall and provides conditions for transforming *A. bisporus* from vegetative to reproductive growth. With a combination of changes in the cropping-environment as the grower reduces carbon dioxide levels and temperature, as would occur naturally in autumn, the filamentous fungus changes to reproductive generation of mushrooms. The microflora in the casing is an essential component of the process and without it no mushrooms would appear. The crop is wholly dependent on the interaction between the crop fungus, the environment chosen by the grower and the beneficial microflora - truly biotechnology in practice.

Because mushrooms are dependent on the microflora of their substrates there are a wide range of opportunities for potential disease-causing fungi, bacteria and viruses to enter the cropping cycle. Many of the most damaging diseases are closely related to the species that *A. bisporus* needs to complete its life-cycle and so may never be eliminated. Constant effort is needed to ensure crops remain healthy - a continuation of the 'battle' to keep the crops 'window of opportunity' open!

TODAY'S INDUSTRY

The UK mushroom industry is in a state of transition as traditional growers completing all aspects of the crop cycle restructure to ensure that they remain competitive. At the same time there are opportunities for expansion of the industry by developing co-operation between specialist growers, composters and marketing companies, a system of concentrating on what each is best at.

Although today the crop is almost exclusively *A. bisporus* there are opportunities for cultivation of a range of 'exotic' mushrooms. A number of other species are grown world wide although often using technology which is not appropriate to the UK. As consumers travel more widely and the benefits of a varied diet are increasingly realised the market for 'exotic' species is set to increase.

In Scotland research programmes include studies of composting biology and the way in which bacteria and fungi interact. The use of beneficial inoculants alongside *A. bisporus* and further studies to make composts more selective in favour of crops are currently being considered. Environmental pressure on commercial compost manufacturers continues to increase and there is an active programme to study ways of reducing pollution of effluent and odour from composting facilities.

OPPORTUNITIES FOR HORTICULTURISTS

The mushroom industry offers opportunities for employment in research in fungal biology, commercial research and servicing industry through advisory services or commercial companies. There is also significant employment in the production industry as an owner-occupier or with major food companies, some of which own large mushroom production businesses. Because of the relatively high level of technology management jobs are generally at graduate entry level.

This development is only one example of numerous exciting innovations which qualified horticulturists are contributing to industry today. If you relish the challenge of helping to shape the future of horticulture, write for more information on courses at degree and postgraduate level to:

Professor of Horticulture
SAC
Auchincruive, Ayr KA6 5HW, Scotland

Appendix 2

Sources of further information / references

Acamovic, A. (1996). Rapeseed meal and full-fat rapeseed as a protein and energy source for pigs. SAC Technical Note T408.

Anon. (1997) Draft National Waste Strategy: Scotland. A Blueprint for Progress 1997 - 2001. Pub. Scottish Environment Protection Agency.

Anon. Betamyl ®1000: Mushroom supplement for use at Spawning. MilliChamp®: The supplement for more mushrooms and better quality. Pub. Trouw (UK) Ltd.

Bragg, N. (1990) Peat and its alternatives. Pub. Horticultural Development Council.

van Griensven, L.J.L.D. (1988). The cultivation of mushrooms. Pub. Darlington (Rustington, UK).

Hall, P.J. (1981) Supplementation of Spawn Run compost. *Mushroom News* **6**. Pub. ADAS, Lea Valley Experimental Horticultural Station.

Randle, P. (1983). Supplementation of mushroom composts - A review. *Crop Research* **23**, 51-69.

Rinker, D.L. (1991). Alternative additives, supplements and casing amendments for *Agaricus bisporus*. *Mushroom Science* **XIII**, 781-789.

Szmidt, R.A.K. (1994). Mushrooms: re-use of compost. Pub. Horticultural Development Council.

Appendix 3

List of Abbreviations

A. bisporus	*Agaricus bisporus*
EU	European Union
^{o}C	Degrees Celcius
fw	Fresh weight
HGCA	Home-Grown Cereals Authority
%	Percentage
p	Probability
pH	Acidity
RMS	Rapeseed meal
SAC	Scottish Agricutural College
SMS	Spent Mushroom Substrate

Appendix 4

Data: Analysis of Variance (Yield)

Summary	*Count*	*Sum*	*Average*	*Variance*
Block				
1	7	54.64	7.805714	18.85356
2	7	30.98	4.425714	21.90423
3	7	19.4	2.771429	19.07798
4	7	20.02	2.86	21.0432
5	7	31.64	4.52	18.3688
6	7	55.04	7.862857	8.855924
7	7	46.76	6.68	9.704267
Treatment				
1	7	**65.66**	9.38	0.369333
2	7	**23.26**	3.322857	15.53379
3	7	**24.78**	3.54	21.66987
4	7	**19.2**	2.742857	13.74752
5	7	**36.8**	5.257143	21.93032
6	7	**21.1**	3.014286	13.17396
7	7	**67.68**	9.668571	1.013048

ANOVA

Variation Source	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	
Block	199.2687	6	33.21144	3.674753	0.005987	3.350692	**
Treatment	381.4893	6	63.58156	7.035121	5.21E-05	3.350692	***
Error	325.3584	36	9.037734				
Total	906.1164	48					

Appendix 4 (continued)

Data analysis for bioassay of growth of A. bisporus vs. test materials in vitro

Treatment	% of self-control	% inhibition vs. control			A = grainy	B = lumpy	Control	A	B	A	B		
1	80	37			80	80	100	37	41.8	46.3	57.9		
1	56.4	50.9			56.4	100	100	50.9	62.7	90.3	69.4		
1	71.4	41.8			71.4	100	100	41.8	52.3	64.8	57.9		
1	61.7	43.9			61.7	88.8	100	43.9	66.9	78.7	83.3		
1	55.9	39.7			55.9	85	100	39.7	71.1	78.7	92.6		
1	105	81.5			105	100	100	81.5	83.6	85.6	92.6		
1	107	85.7			107	73	100	85.7	56.5	88	85.6		
1	123	66.9			123	47.6	100	66.9	41.8	60.2	97.2		
1	140	43.9			140	100	100	43.9	87.8	34.7	97.2		
1	56.3	37.6			56.3	65	100	37.6	27.2	74	46.3		
1	94.1	33.5			94.1	116.6	100	33.5	43.9	39.4	41.7		
1	64.5	41.8			64.5	95.5	100	41.8	43.9	71.8	50.9		
1	105.5	39.7			105.5	67.5	100	39.7	83	41.7	123.1		
1	53.8	43.9			53.8	106	100	43.9	107.7	90.3	101.5		
2	80	41.8											
2	100	62.7											
2	100	52.3											
2	88.8	66.9											
2	85	71.1											
2	100	83.6											
2	73	56.5											
2	47.6	41.8											
2	100	87.8											
2	65	27.2											
2	116.6	43.9											
2	95.5	43.9											
2	67.5	83											
2	106	107.7											
3	100												
3	100												
3	100												
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3	100												
3	100												

Analysis of growth effect overall in relation to controls

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A	14	1174.6	83.9	805.7015
B	14	1225	87.5	357.7508
Control	14	1400	100	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F Crit*
Between Groups	1999.293	2	999.6467	2.577622	0.088839	3.2381
Within Groups	15124.88	39	387.8174			
Total	17124.17	41				

Analysis of reduction specifically towards test material

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A	14	687.8	49.12857	276.6022
B	14	870.2	62.15714	505.7949

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1188.206	1	1188.206	3.037347	0.093186	4.2252
Within Groups	10171.16	26	391.1986			
Total	11359.37	27				

Analysis of growth reduction away from test samples

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A	14	944.5	67.46429	395.404
B	14	1097.2	78.37143	597.9037

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	832.7604	1	832.7604	1.676742	0.206739	4.2252
Within Groups	12913	26	496.6539			
Total	13745.76	27				