ADAPTING TO CLIMATE CHANGE

01. ENERGY GENERATION FROM SPENT MUSHROOM COMPOST

Summary

It is estimated up to 350,000 tonnes of spent mushroom compost (SMC) is produced annually. Although a waste product, it retains valuable carbon and nutrients. Potential uses of SMC include re-composting into new substrate, combustion to generate energy, or production of biogas plus nutrient-rich digestate. Biomass combustion systems vary in their efficiency. Biogas can generate heat and energy for use on farm, while biomethane for fuel is possible with additional steps. There is emerging use, including commercial applications, of biogas and biomethane produced from SMC in Europe, and in conjunction with other technologies can convert remnant waste SMC into fertilizer and building products.

Background

It is estimated that each kg of mushrooms requires production of 3-5kg compost. At least 70,000 tonnes of mushrooms are produced annually, suggesting up to 350,000 tonnes of SMC is potentially available for energy production. Farms usually sell or give away their SMC, or may even pay to have it taken away.

It may be possible to recycle SMC, mixing it with new materials and additives to make new substrate for mushroom production. However, impediments include concern about pests and diseases, transport costs back to compost facilities considerable distances from farms and the mixing of compost with casing during removal at the end of the crop.

Using SMC to generate energy has a dual benefit of utilising an existing waste product, while directly reducing energy costs. Adopting this practice would significantly reduce the environmental footprint of mushroom production, moving it closer to 'carbon neutral'. With this comes environmental, financial and marketing advantages.

Energy for cooling, heating and equipment is one of the biggest costs of operation for both composting facilities and mushroom farms. Energy costs are generally highest in summer to meet cooling requirements. Rising temperatures are likely to increase costs, as farms build in capacity for more frequent, extreme and lengthy heatwaves. Major energy uses on farm include:

- Cooling / heating of grow rooms
- Heat and steam generation during room cookout
- Cooling / heating of processing and packing areas
- Postharvest cooling and storage of mushrooms
- Equipment such as forklifts, pumps, fans, belts etc.

SMC can potentially be burned to produce heat – which can then directly heat steam for cookout, or generate electricity to run the farm. It can also potentially be used to generate biogas. Biogas can also generate heat directly, generate electricity, or be further refined into an LPG equivalent to run forklifts and trucks. These options will be discussed.

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01. ENERGY GENERATION FROM SPENT MUSHROOM COMPOST

Biomass combustion

The simplest way to produce energy on-farm is through combustion of SMC.

A study by Finney et al[1] examined using raw SMC (including the casing material) and pelletised coal tailings (mining waste) to generate energy. Three methods were tested:

1. ***Fluidised bed combustion*** – fuel is placed on a bed of heated sand with jets of oxygen blown through it, promoting rapid high temperature oxidation
2. ***Packed bed for combustion and gasification*** – solid fuels are oxidised on a grate with air supplied from below, reaching very high temperatures (>1,000°C)
3. ***Pyrolysis*** – materials are heated to extreme high temperature in the absence of oxygen, producing energy plus stabilised carbon “biochar”

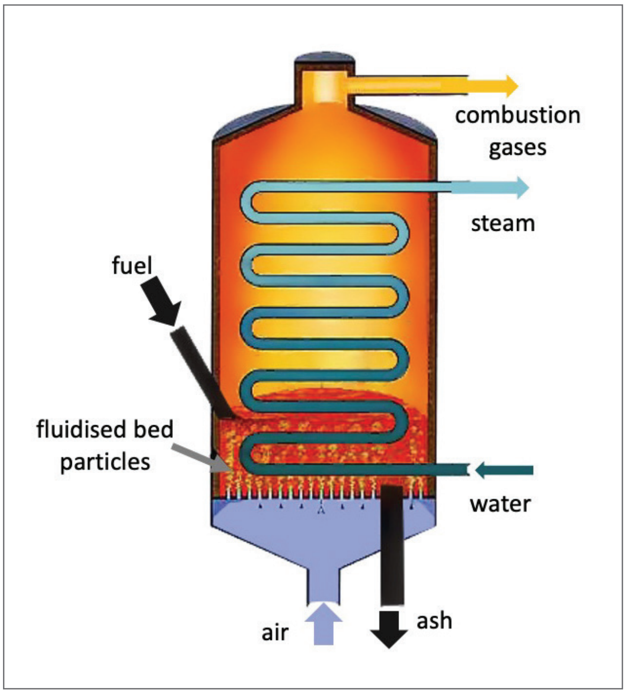

Figure 1. Fluidised bed combustion (From photomemorabilia.co.uk)

The fluidised bed produced more energy than the packed bed. However, both methods were self-sustaining and produced useful amounts of heat and, therefore, power. The process was improved if the SMC was combined with coal tailings and pelletised, as pellets burn more efficiently. While pyrolysis produced reasonable volumes of biochar as well as liquid and gaseous fuels, the authors considered yields were not high enough to justify investment in this technology.

Compost was dried to 15% moisture content before it could be burned. Biomass combustion is much more efficient if wet casing is separated from the underlying SMC.

The Mush Comb system has been developed in the Netherlands to separate casing from the compost at the end of the cropping cycle. Primarily aimed at shelf farms, the system could be adapted for tray systems (B. Holtermans, pers. com.).

Removing the casing layer at least doubled the energy potential of SMC in trials conducted in the UK. The casing layer contains a high level of chalk, which does not burn. According to Dr John Burdon, removing the casing, pelletising, and using efficient fluid bed boilers could make SMC a viable fuel for energy production.

Bio-hydrogen

Researchers in Taiwan[2] have developed a process to convert SMC to hydrogen gas. Hydrogen is considered a potential alternative to fossil fuels for powering vehicles. One of the benefits is that burning produces only water.

The production process is complex, involving grinding the compost, reacting it with sulfuric acid, then combining with sewage sludge and heating to 37°C to produce hydrogen, along with other compounds. Although a potentially useful technology in the future, it is in early stages and likely to be expensive to implement on farm.

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1 Finney KN, Ryu C, Sharifi VN, Swithenbank J. 2009. The reuse of spent mushroom compost and coal tailings for energy recovery: Comparison of thermal treatment technologies. Bioresource Tech. 100:310:315.

2 Li Y-C et al. 2011. Hydrogen production from mushroom farm waste with a two-step acid hydrolysis process. Int. J. Hydrogen Energy. 36:14245-14251.

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Biogas production

WHAT IS BIOGAS?

Biogas is produced by the anaerobic digestion of organic matter. It is typically 50-70% methane and 25-45% CO_2 with other gases in small volumes. Biogas can be easily be stored, then used as needed to provide heat (e.g. steam for cookout) or generate electricity. The process also produces nutrient rich digestate, useful as fertiliser[3].

Alternatively, hydrogen can be added, converting the biogas into biomethane, a product equivalent to natural gas. Compressed biomethane can be used to power vehicles. For example, Waitrose in the UK has introduced a fleet of 50 compressed biomethane-fuelled trucks, reducing their CO_2 emissions by more than 80%[5]. Biomethane is also being used to fuel buses in Nottingham and British Post Office long-haul trucks[6].

Biogas has a number of advantages over solar and wind for energy generation. They can provide a continual supply of electricity and heat, are relatively unaffected by environmental conditions and provide a high rate of returns for the space occupied[7].

According to the World Biogas Association, converting more organic wastes to biogas could reduce global emissions by up to 12% by 2030[8]. Although there are an estimated 132,000 small, medium and large digesters around the world, in 2017 there were only 242 in Australia, half of which were landfills. The Australian Renewable Energy Agency[9] (ARENA) recently (2019) commissioned an extensive review of biogas opportunities for Australia. The review can be downloaded here [10].

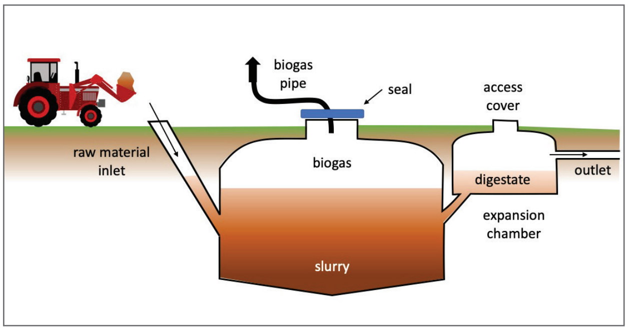

Figure 2. Derived from Tilley et al., 2014[4].

Figure 3. Waitrose truck powered by biomethane. Photo by Scania Waitrose.

	BIOGAS	WIND	SOLAR
Units	8,000 KWh	2,000 KWh	850 KWh
Generation capacity	3 MWe	2 MWe	0.6 MWe
Yield	24 GWh	4 GWh	0.53 GWh
Households potentially supplied	8,000	1,333	176

Table 1. Energy yield per 1.5ha of space used. From Christiaens, 2009.

3 Carlu E, Truong T, Kundevski M. 2019. Biogas opportunities for Australia. ENEA Consulting.
4 Tilley E. et al. 2014. Compendium of Sanitation Systems and Technologies. 2nd Revised Ed. Swiss Agency for Development and Cooperation. https://sswm.info
5 www.waitrose.com/home/inspiration/about_waitrose/the_waitrose_way/caring_for_the_environment.html
6 Morton C. 2019. Decarbonising transport: the biomethane solution. https://advancedfleetmanagementconsulting.com/eng/2019/11/03/decarbonising-transport-the-biomethane-solution/
7 DeBeer E. 2014. https://edwarddebeer.wordpress.com/2014/02/26/biogas-vs-wind-energy-vs-solar-energy-2/
8 Anon. 2020. Putting biogas at the heart of the economy. Energy World, February 2020. p22-24.
9 ARENA https://arena.gov.au
10 Biogas opportunities for Australia (March 2019) https://arena.gov.au/assets/2019/06/biogas-opportunities-for-australia.pdf accessed 14/2/2020

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USING SPENT COMPOST TO PRODUCE BIOGAS

Four key factors determine the feasibility of biogas for mushroom growers:

1. The suitability of spent mushroom compost and mushroom waste as a substrate for biogas
2. The quantity of spent mushroom compost and mushroom waste available each day
3. The cost of electricity
4. Capital investment required and the payback period

There has been considerable work on generating biogas from mushroom farm wastes, particularly trimmed stalks and spent mushroom compost (SMC). The process could provide extra value for mushroom farms as biogas digestors produce CO_2, which can be used in growing rooms to control pinning.

A recent review of biogas production notes that fungi are effective at breaking down lignocelluloses in different types of organic wastes. This makes the compost easier for the biogas-producing microbes to digest, removing the need for pre-treatment with physical or chemical processes[11].

However, it is still unclear how much biogas can be produced from SMC, and the extent to which this is affected by the inclusion or not of the casing layer. According to Dr Thomas Helle, (Novis GmbH, Tübingen, Germany), mushroom compost is difficult to ferment, being low in nutrients and high in insoluble fibre. However, addition of certain fungal additives and enzymes can increase biogas production by 200-300%[11]. Increasing the temperature also helps to reduce salt content in the digestate produced.

THE SMARTMUSHROOM PROJECT

The “SmartMushroom” project (www.smartmushroom.eu) currently underway. in Europe is testing production of biogas from SMC. The aim is to recycle SMC (including casing) into biogas plus a pelletised organic fertiliser.

The SMC is digested using a two-stage anaerobic process. Biogas produced can be used to generate electricity, as well as fuel a dryer to remove moisture from digestate and remaining SMC. The dried material is pelletised (along with additional nutrients if required), forming a readily transportable organic fertiliser.

A pilot plant has been built in La Rioja, Spain’s largest mushroom growing area. The plant is using wastewater from a nearby jam factory (which is high in sugar) plus glycerine (100% organic dry matter) as co-substrates. The plant uses 2t of SMC daily, producing approximately 343,000L of biogas. This is used to run a dryer at 65-80°C, processing the remaining SMC and digestate into fertiliser pellets.

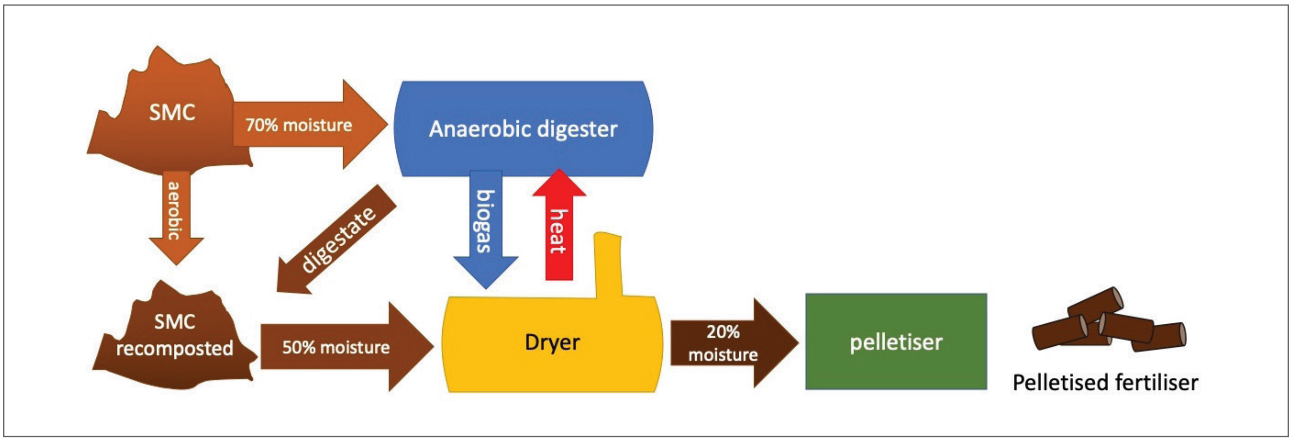

Figure 4. The SmartMushroom process. Derived from www.smartmushroom.eu

11 https://biooekonomie.de/en/interview/biogas-mushrooms

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The refined SMC is an excellent source of phosphorus, potassium, nitrogen and trace elements, with a C:N ratio of 20:1 or less. Initial trials have been conducted using pellets formulated for a range of vegetables including tomatoes, cucumber, capsicum and leafy greens. The pellets improved root development and promoted earlier flowering and fruit development compared to control plots.

The economic feasibility study suggests that a plant capable of processing 10,000t SMC annually would have a payback time of 4.3 years and a pre-tax internal rate of return of 21%. While this includes a saving from not having to pay to dispose of the SMC, it does not include any income from supplying electricity to the grid;

Construction cost = 2.2 million euro
Operating cost = 307,000 euro/year
Throughput = 10,000t/year
SMC utilisation savings = 6 euro/t = 60,000 euro/year
Powerplant size = 1.25 megawatts thermal
Pellet sales = 90 euro/t

More detailed results will be available after July 2020. If successful, further plants are planned in six European countries.

IMPROVED SUSTAINABILITY THROUGH BIOGAS

Digestate from biogas production also has other uses. There is interest in testing this material as a partial replacement for peat, although salt content may prove limiting. The digestate also contains readily extractable fibres. German researchers[91] are developing natural fibreboards based on combining these fibres with bio-based resins. The boards have properties that may make them superior to wood-based boards and are readily composted at the end of their life cycle.

Even without these processes, biogas offers an opportunity for sustainable use of resources[12]. With 350,000 tonnes of spent mushroom compost SMS produced each year in Australia it should be considered as a promising alternative for clean energy production as mono- or co-substrate in anaerobic digestion.

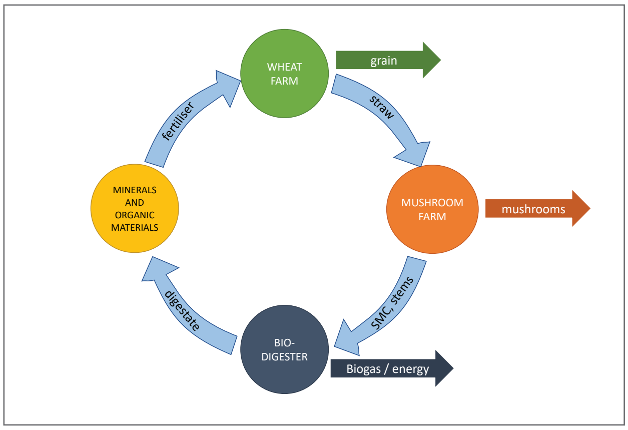

Figure 5. The "virtuous circle": sustainable production of biogas from mushroom wastes. Derived from Perez-Chavez et al. 2019[11].

There are a number of companies offering biogas systems in Australia - including:

- Bioenergy Australia.
  https://www.bioenergyaustralia.org.au
- Utilitas
  https://utilitas.com.au/
- Biogass Renewables Pty Ltd.
  http://www.biogass.com.au/
- Hitachi Zosen INOVA
  http://www.hz-inova.com/cms/en/home/
- ReNu Energy.
  https://renuenergy.com.au/

Biogas system providers can test SMC for suitability and advise on the payback period on capital investment. Costs may further be offset by sales of credits to the LRET scheme or funding through the Australian Renewable Energy Agency (ARENA).

For example, in 2014 Utilitas conducted a study on biogas production from vegetable wastes. At that time, electricity could be produced by biogas for about $80 - $160/MWh, with a payback period on capital investment of five years. Electricity returned to the grid earns a maximum of $110/MWh, so biogas is only economically viable if energy produced is used on-site. However, this is unlikely to be an issue for mushroom farms as energy is readily utilised on-site.

12 Perez-Chavez AM, Mayer L, Alberton E. 2019. Mushroom cultivation and biogas production: A sustainable reuse of organic resources. Energy for Sustainable Dev. 50:50-60.

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