Mushroom Compost

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Introduction

- Worldwide edible mushroom production on agro-industrial residues comprises of more than 11 million tons of fresh mushrooms per year.
- Waste problem: For 1 kg of mushrooms there is 5 kg of spent mushroom compost (SMC) which is a waste with disposal problem.
- Waste to Wealth: SMC contains mycelium and high levels of remnant nutrients such as organic substances and macro elements (N, P, K).
- The spent mushroom is being tried for reuse in agricultural and horticultural production.
- Recently, the increase of the global environmental consciousness and stringent legislation have focused research towards the application of sustainable and circular processes which together make a circular economy.
- Circular economy implies that agricultural waste will be the source for retrieving high value-added compounds.

Current Disposal Practices of SMC

- The substrate after growing mushrooms is usually a problem for their producers, who are most willing to get rid of the compost after harvest.
- The average mushroom farm throws about 25 tons of SCM per month.
- Cultivation remnants and the substrate itself attracts flies and other insects that can transmit diseases and are a potential source of water and air pollution.
- Some of the current disposal strategy of SMS/SMC in the world is by burning, spreading on land, burying, composting with animal manure, or very much common by landfilling.
- Environmental regulations have forced mushroom farmers to look for more environmentally friendly ways of utilizing residual substrates.

- Most commonly, the research on SMS/SMC is focused on the enzymatic activity of the residual mycelium and its ability for production of lignocellulosic enzymes such as laccase, xylanase, lignin peroxidase, cellulase and hemicellulase as a cheap source of bioremediation, animal feed and energy feedstock.
- The demand for organic fertilizers and compost increased due to increasing restrictions on the use of synthetic pesticides and mineral fertilizers in agricultural and horticultural cultivation.

Mushroom substrate types

- Mushrooms are cultivated on a specially designed and selective medium that supplies the nutritional requirements of the mushroom crop.
- The best substrates are composed from so called agricultural wastes rich in lignocellulose components which are difficult to break down; however, can be effectively be done by mushrooms.
- Their composition and method of preparation varies depending on the availability and geographic location of the crop.
- Depending on which mushroom is cultivated there are two kinds of substrates for cultivation: composted and pasteurised substrate to or sanitised with pasteurisation or sterilisation.

Mushroom Compost

- One of the most popular commercial blends of mushroom substrate is a mix of wheat straw, gypsum, and horse or chicken manure. Other ingredients can be used, but these are some of the most common.
- To produce industrial-level quantities of this particular mushroom compost, a manufacturer will begin with large bales of wheat straw. Bales of straw are dunked in water and allowed to soak for a few minutes, fully saturating them like a large sponge. The straw is then run through a chipper to make it into a finer particulate.
- Meanwhile, the manure and gypsum will be blended together thoroughly, and then the straw worked in. This mixture will be placed in hot compost piles. They are watered and turned daily to begin the composting process. This process can take up to two weeks.

- Once the initial hot stages have concluded, killing off any wheat seeds that remain, the piles are turned into long rows and allowed to compost down for another couple of weeks. This secondary composting slowly turns the piles into a rich chocolate brown colour.
- The resulting compost is then pasteurized to kill off any remaining bacteria or weed seeds that might have gotten in during the composting phases.
- The pasteurization fully sterilizes the wheat/manure/gypsum blend and creates a perfectly clean material.

Characteristic of Spent Mushroom Substrate – SMS /Spent mushroom Compost SMC

- Both types of substrates can be retrieved for direct use, are high in organic matter (22–40%), which can be a good source of nutrients for plants, mainly due to its rich content of nutrients, high cation exchange capacity and slow mineralization.
- However, their characteristics differs in terms of their initial components and methods of preparations.
- The amount of mineral elements constitutes for 66–78%.
- SMC is a good source of general nutrients such as NPK (1.3–4.2:0.1–0.4:0.5:1.8% respectively), Mg (0.2–0.4%), Na (0.05–0.2%) and full range of trace elements such as: Cu, Fe, Mn, Zn, Mo, B (values in ppm: 4–12; 1000–2500; 100–300; 50–200; 1–2; 6–15) and soluble salts does' not contain any pests or weed seeds.
- In addition, SMC contains 45% water, although it seems quite condensed substrate compared to manure, it has a low bulk density

- One cubic meter of SMC corresponds to 2 to 3 tonnes of solid manure in terms of nutrient content. It contains about 6–20% calcium in the dry matter, thanks to which it has deacidifying properties

Uses of SMS

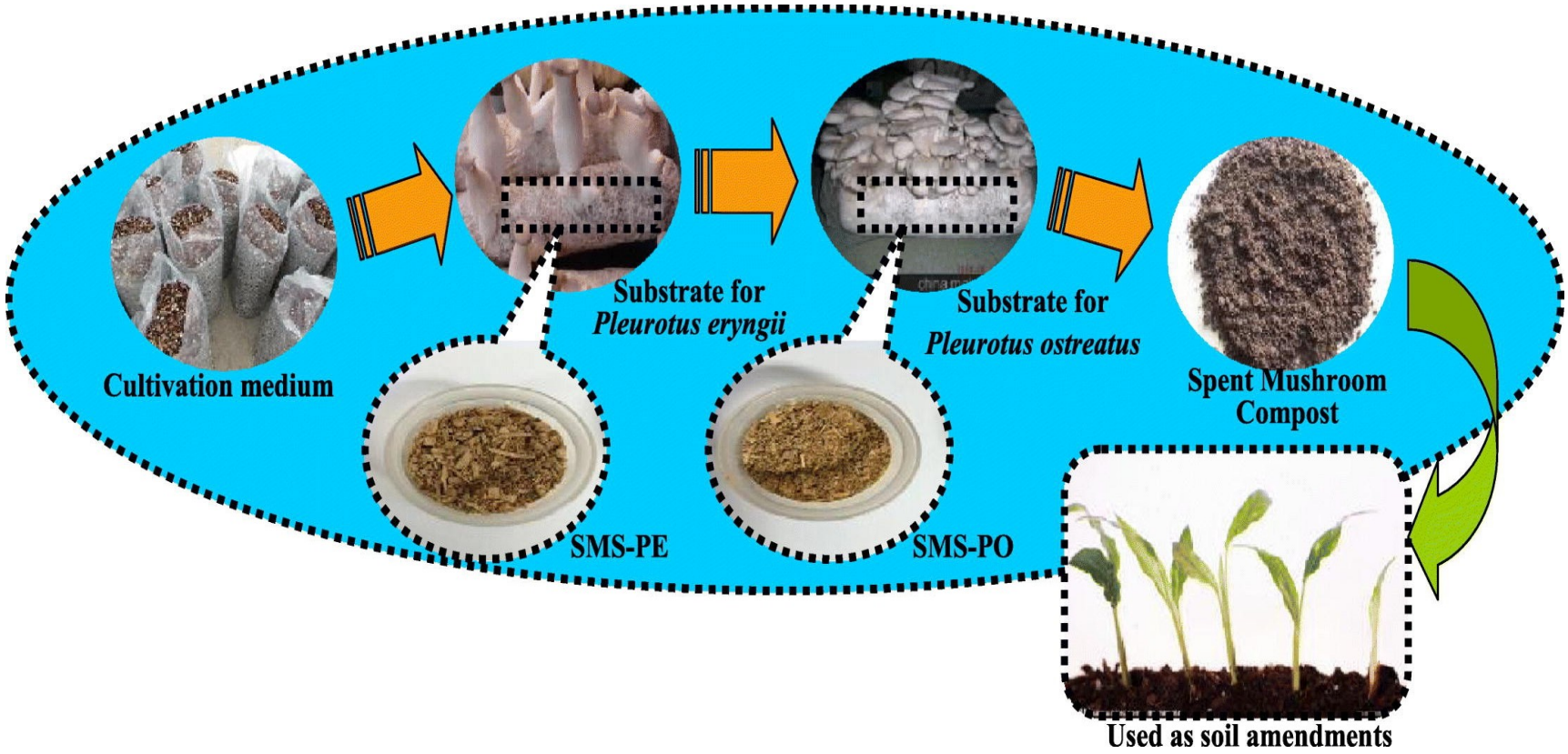
Recultivation of other mushrooms

- The substrate (SMS) may be reused after cultivation of one species of fungi to grow the same or other species of fungi. Thus better use of the remaining nutrients help to reduce problem of SMS removal.
- The most research show that the most common is recultivation of various *Agaricus* species or *Shiitake* on substrates after cultivation of specialty mushrooms, most commonly oyster mushroom.
- Low rate of contamination in case of *A. blazei* cultivation has been reported when it was grown on a mixture of non-composted substrates and spent mushroom substrate as the main component or when a combination of spent mushroom and sunflower seed hulls were used in 50:50 ratio.
- Some studies show recultivation of *Pleurotus mushroom* on *Shiitake* SMS supplemented with some nitrogen sources such as wheat and rye bran, soya seeds, $CaCO_3$

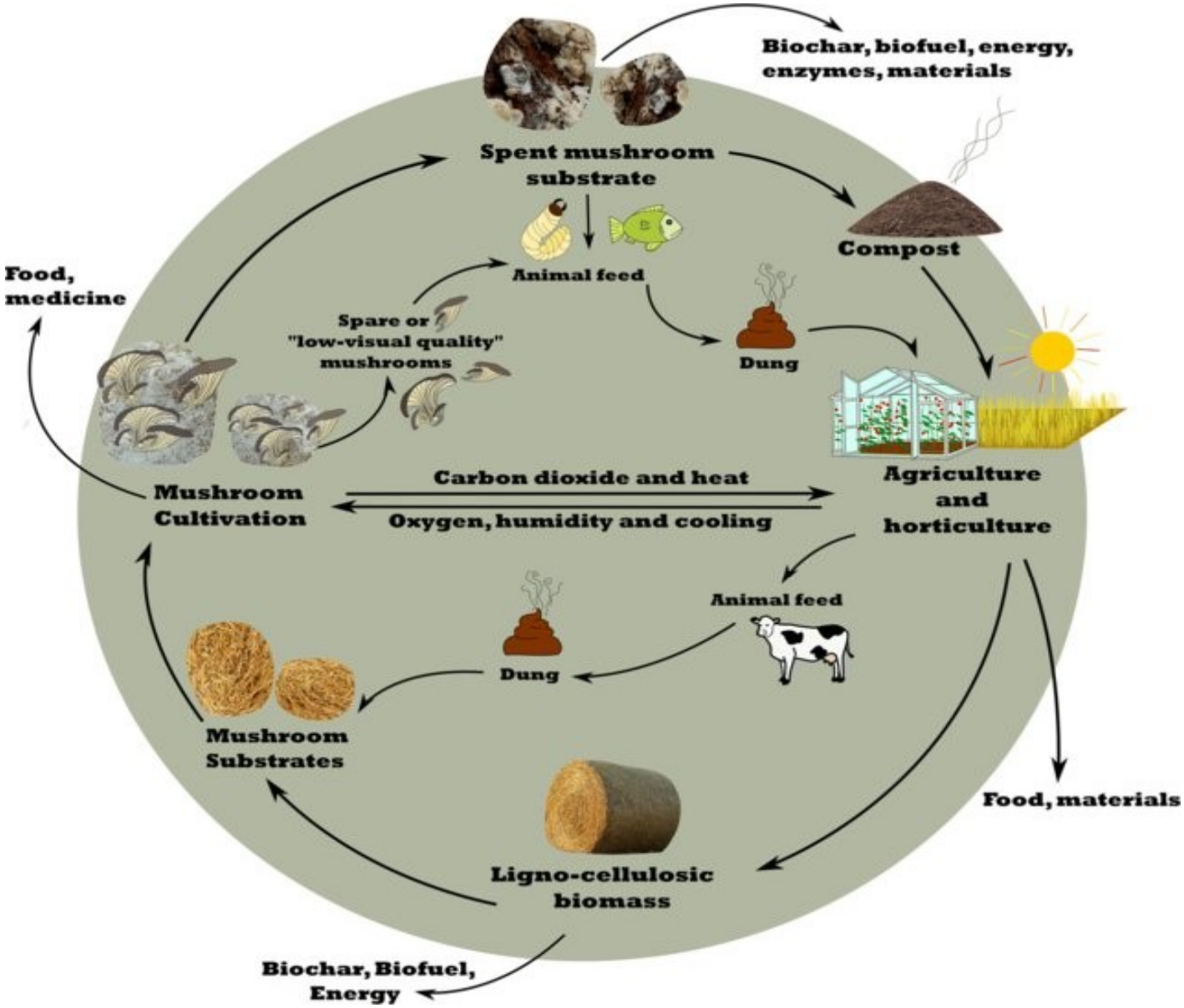
- Reuse of the SMS of *Volvariella volvacea* has been performed for the cultivation of *Pleurotus pulmonarius* resulting in good yields of fruiting bodies.
- Similarly, SMC of *Agaricus bisporus* has been used for cultivating of *Volvariella volvacea*.
- Reuse of SMC obtained after *A. brasiliensis* cultivation has been reported for *Pleurotus ostreatus, Agrocybe cylindracea* and *Hericium erinaceus* cultivation.
- Advantage of this substrate is the low content of mineral salts, sulphates and pH close to the neutral pH 5.1–6.0, which is achieved through long period of mushroom harvesting – 110 days, because of which it can be used immediately after cultivation, without the need for prior composting.

Role of SMC as an addition to the casing or as a casing soil

- In commercial *Agaricus* mushroom cultivation so called casing soil is used to cover the compost, after the substrate is fully colonized by mushroom mycelium to encourage fructification.
- The spent *Agaricus bisporus* compost has been looked upon as a cheap alternative to **casing soil,** (generelly made from Sphagnum peat moss).
- SMS as a casing has promising features with high water holding capacity and low bulk density but it is characterised by high EC (electrical conductivity).
- As the casing from SMS is having a high EC, it is either aged, leached or mixed with some other organic components to dilute its EC.
- Examples include (i) use of aged SMS as an ingredient of casing mixtures with coconut fibre in new cycles of mushroom cultivation (ii) use of chelating agents like citric acid, ethylene diamine tetra acetic acid (EDTA) to reduce metal cations from the SMS to reduce it EC and then using as casing (iii) use of SMC as casing also reduced the risk of bacterial blot on fruiting bodies better than with the traditional peat-based casing.



Use of spent mushroom compost



MUSHROOM CIRCULAR ECONOMY

Horticulture

Combined cultivation with plants

- Combined or combination cultivation is the process of mixing different kinds of crops with each other because it has been observed that crops positively influence each other, which has some advantages: prevention of pests and diseases, larger yields and healthier plants.
- However, not only plan-plant systems are known and described, but also plant-mushroom.
- The best and the most know example of mushroom-plant system is omnipresent mycorrhiza dependence between higher plants and mushrooms.

- Mushroom hyphae wrap around roots and increase water and minerals availability for plants, thus higher biomass production, higher yields.
- On the other hand, mushroom compost is nutrient rich product, highly assimilable by plants.
- *Stropharia rugoso-annulata* is grown together with maize – 20% of yield increase, while combination of *Hypsizygus ulmarius* and Brussel sprouts results in 25% increase in yield.
- Co-cultivation of edible mushroom- *Agaricus brasiliensis (also known as **A. subrufescens,** Agaricus blazei or Agaricus rufotegulis)*, and vegetables – *Vigna unguiculata*, provides a sustainable cultivation strategy: The climbing plant forms shade for the mushroom and creates a specific microclimate, on the other hand CO_2 produced by mushrooms in respiration process is used by plants for plant tissue production.

Agaricus brasiliensis

Organic fertiliser

- A common way to use of SMC is to use it as an organic fertilizer in agriculture and gardening.
- The advantages of using SMC as a soil fertilizer over a chemical fertilizer is that it delivers slow-release of nutrients that will not burn crops upon application.
- Besides, SMC has a low bulk density that indicates it is a relatively porous medium that can enhance the structure of the soil when added to it.
- However excessive application of SMC to the soil can lead to nutrient losing through leaching, which may cause water or soil pollution.
- One method of pre-treatment of SMS before use is, passive leaching by rainfall and snowmelt.
- Another is the application of biochar, which could prevent the loss of nutrients from SMC.

- Others have suggested the production of biochar from SMS or SMC in order to improve nutrient retention during SMC application.
- Study suggest that combined application of SMC and SMS based biochar was an effective strategy in nutrient conservation without any extra material consumption.
- On the contrary, spent mushroom compost leachates can be used in plant culture as a rich source of nutrients.
- Seedlings of tomato and marigold were treated with amendment leachates from SMC and commercial composting site showing species dependent response.
- While tomato showed good growth in amendment commercial compost leachate, but poor growth in SMC amendment leachate, whereas excellent, growth of marigold was observed in SMC amendment leachate. However, SMC should be used in amounts not exceeding 50% – as the EC levels become difficult to maintain.

- Application of air-dried mixed *Pleurotus* SMS and *Agaricus* SMC and their leachates resulted in overall increase of growth and protein, chlorophyll and carotenoids content in pepper plants.
- However, a limitation of SMC/SMS application results in nitrogen deficiency as it remains immobilized in straw and mycelium and may causes temporary malnutrition in plants.
- Yields of sweet corn, cabbage and potato were increased when SMC was supplemented at 40 and 80 t ha^{-1} (moist), however temporarily immobilization of nitrogen occur at 20 t ha^{-1}, suggesting addition of inorganic fertiliser.
- Addition of spent mushroom substrate to the soil approximately one month prior to the planting has been suggested for better results.
- Addition of spent mushroom substrates has also been shown to increase soil respiration rate and phosphatase activity.

- SMC has been used as an alternative substrate /medium for the production of vegetable seedlings, among others lettuce, tomato, pepper, pumpkin, cucumber, tomato, broccoli, tulip, cauliflower, peppers, spinach etc

Pre-processing

Composting for soil amendment

- Due to the high content of mineral salts, and high content of sulphates, which can inhibit the growth and development of plants, the most common treatment for the SMC to be used is composting.
- During this process, the excess of mineral salts is washed out so that the substrate can be reused as an organic fertilizer for the cultivation of cereals, fruits, vegetables and ornamental plants.
- A two-stage composting of green waste consisting of park and garden litter and trimmings, with SMS (35%) and biochar (20%), produced compost of the highest quality in the shortest time of only 24 days.
- It was also observed that this combination extended the duration of thermophilic period, enhanced particle size distribution and nitrification, and increased microbial numbers, enzyme activities, and nutrient content during composting, which consequently accelerated the degradation and humification of organic wastes in two-stage composting.

- Co-composting of SMS in the following ratio: carnation waste (50%) , chicken manure (20%) and spent mushroom compost (25%) resulted in a stable compost with better soil amendment properties.
- Co-composting of sewage sludge (SS) with mushroom substrate (SMS) and wheat straw (WS) conducted for 20 days suggested that adding SMS and WS could not only improve the degradation of organic matter and the quality of compost product, but also stimulate ammonia assimilation and reduce ammonia loss.
- Biogas residues and SMS compost have been reported to be good alternative to peat, allowing 100% replacement, and that 20–50% replacement produces tomato and pepper seedlings with higher morphological growth and lower *Fusarium* contamination.
- Overall it can be said that composting is an appropriate treatment to transform fresh organic matter (OM) from SMS into humified forms, thus enhancing their quality, agronomic efficiency, and environmental safety as a soil OM resource for application as soil amendment.

Vermicomposting of SMC/SMS

- Vermicomposting could be considered as an alternate technology for recycling and environmentally safe management of SMC using earthworms.
- The studies showed that the vermicomposted SMC was rich in the micro and macronutrients which are essential elements for plant growth, had good physical properties, low conductivity, low C: N ratio, optimal stability and maturity.
- Earthworms like *Eisenia fetida,* and *E. andrei, and Lumbricus rubellus* have been reported for vercomposting of SMS/SMC

THANKS