Reuse of Spent Mushroom Compost for Energy Recovery

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Introduction

- The mushroom growing industry generates about 200 kton/yr of spent mushroom compost (SMC). With the nutrients "spent", this material is not suitable for reuse in agriculture and it is now deposited in landfill.
- This study is to divert SMC from landfill in an environmentally friendly manner through its reuse with coal slurry binder to manufacture fuel rich pellets for energy recovery.
- SMC contains a significant amount of biomass; hence energy recovery from this particular fraction will be greenhouse gas neutral.
- There are several million tons of coal slurry available at the colliery sites in Yorkshire and Northumberland. Fortunately, much of the available SMC is reasonably close to these cola slurry lagoons.
- In the form of pellets, the SMC/sludge can be easily transported and will flow nicely through feed hoppers. The pellets will be suitable for use in chain grate furnaces, industrial gasifiers, or fed into the mills of conventional pulverised fuel based power stations.

Spent Mushroom Compost (SMC)

Mushroom Compost
- Used for button mushroom production in mushroom farms
- Compost: straw, poultry manure, horse manure and gypsum after 3 weeks of production process (Phase II compost)
- Casing layer: peat and chalk
- Mushroom Compost for UK is mostly imported from Holland.

Generation of SMC
- ~5kg per 1kg of mushroom
- over 200 kton/yr in the UK.

Disposal of SMC
- mostly landfilled as agricultural waste
- Environmental Impact on landfill of SMC
  - Contamination of groundwater and rivers due to high phosphorous content of SMC
  - Leaching of nitrate (NO_3^-) and some compounds used for sterilisation or as pesticide

Spent Mushroom compost

Coal Slurry

Coal production from deep mines in the UK
- 206 million tonnes in 1950 → 12.5 million tonnes in 2004

Coal slurry
- Fine discard (a few micron – 0.5mm) from coal cleaning
- ~7.5% of the total coal mined (estimated 930 kton/year in 2004)
- Accessible and abundant material deposited in lagoons
- Land reclamation for some old lagoons

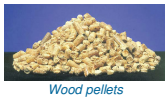
Current use of coal slurry
- Power generation only for minor fraction of coal slurry with 15-20% of ash content

Pelletisation Technologies

Benefits of pelletisation
- Material and energy densification: reduces transportation cost
- Easy handling, storage and feeding
- Standardisation of fuel properties required for market outlet

Pelletisation method
- Compression: piston and mould, roll press
- Extrusion: pelleting mill, screw pelletiser
- Control parameters: pressure, temperature, time, binding agent, additives
- Examples of fuel pellets: solid recovered fuel (SRF) from municipal solid waste, wood pellets from forestry residues
- Key properties as fuel: particle size, calorific value, moisture content, strength and durability


Solid Recovered Fuel (SRF)


Wood pellets

Material Characterisation

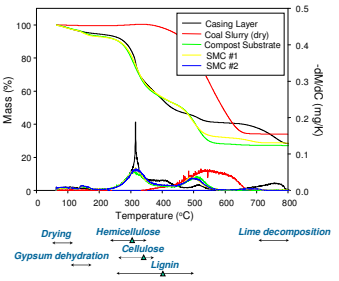
SMC and Coal Slurry as Fuel
- Drying is essential: about 70% of moisture content for SMC, over 30% for coal slurry
- Calorific value with 20% of moisture content: 9.5 MJ/kg for SMC, 17.9 MJ/kg for coal slurry
- Although the calorific value is lower than wood pellets or SRF, reuse of wasted materials is required for which pelletisation is essential.

Materials		SMC	Coal Slurry	Wood pellet	SRF
Moisture content (raw material)		**~70%**	**>30%**	~10%	<5%
Proximate analysis (%dry)	Volatile matter	53.57	25.07	85	67
	Fixed carbon	12.43	30.79	15	13
	Ash	**34.00**	**44.14**	<0.5	20
Ultimate analysis (%dry)	C	39.86	52.31	55.0	49.0
	H	3.80	3.29	6.7	6.6
	N	**2.12**	0.84	0.2	1.0
	Cl	1.10	0.64	<0.01	<2.0
	S	0.62	**1.44**	<0.01	<0.3
Gross Calorific Value	MJ/kg-dry	11.9	22.4	~21	~22
	MJ/kg @ 20%water	**9.5**	**17.9**		

Trace Elements

Element (ppm)	SMC	Coal Slurry	Note for SMC
Aluminum	200	4400	
Calcium	**20500**	1860	*Gypsum*
Iron	535	9300	
Potassium	**5500**	1075	*Alkali metal*
Sodium	**1340**	605	*Alkali metal*
Phosphorous	**1900**	60	*Key nutrient*
Zinc	50	30	
Lead	1.4	11	
Chromium	1	10	

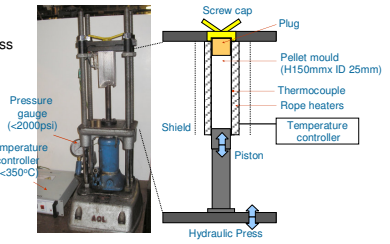
Thermogravimetric Analysis

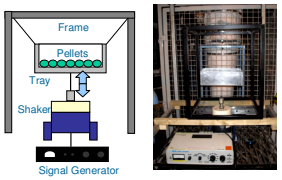


Pressure Pelletisation

Pelletisation Method
- Cylinder mould seated on a hydraulic press
- Pellet diameter: 1 inch
- Tested pressures: 400-1000 psi
- Tested temperatures: 15~120°C

Key Parameters
- Moisture content in material
- SMC/Coal slurry mixture composition
- Pressure
- Temperature





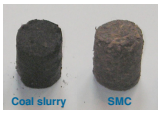
Durability Test Rig

Assessment of Pellet Quality
- Pellet density
- Drying over time (moisture content)
- Tensile strength: maxi. pressure a pellet can take
- Durability: resistance to vibration/collision during transportation

Experimental Results (Preliminary)

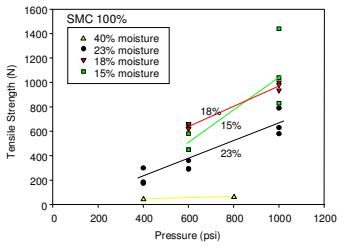
SMC 100% pellets : drying is essential for pellet quality
- 10 times harder pellets when dried to 15% of moisture content from 40%.
- Cracks develop during air drying for high moisture content pellets.

Coal Slurry
- Weak and less durable without binding agents.
- Mixing with SMC can make harder pellets.



Material		Coal Slurry (Air dried)	Raw SMC	
Pressure applied		800psi	400psi	800psi
Initial moisture content		1.5%	44%	40%
Density (kg/m^3)	1 hour	1288	1127	1140
	2 week	1252	858	821
Tensile Strength (N)	1 hour	63.3	43.1	50.0
	2 week	65.0	48.3	60.7
Durability (%)	2 week	64%	80%	92%

Properties of Coal slurry and SMC pellets produced at room temperature



Tensile strength of air dried SMC pellets

Conclusions

Pellet production from SMC and coal slurry is promising

Moisture content of pellets is the key factor for pellet quality
- Ideal moisture content: ~15% for SMC (drying raw materials is essential required)
- Increases calorific value and pellet strength.
- Enables homogeneous mixing of materials.
- Sterilises SMC to some extent preventing mould.
- Lignin in SMC softens at elevated temperatures- harder pellets.

Future work
- Pelletisation for more test cases to identify ideal pelletisation conditions (moisture content, pressure, temperature and composition)
- Cost analysis (production and transportation)
- Investigation of extrusion pelletisation

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More Information on SUWIC can be found at our websites: http://www.suwic.group.shef.ac.uk/

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