Making Biomass Briquettes from Wheat Straw Biofiller Production Waste

Subtitle: Wheat Straw Combustion

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OMTEC Product Development

- BIOFILLER PRODUCTS
- WHEAT STRAW BRIQUETTING
- WHEAT STRAW COMBUSTION

OMTEC Product Development Pipeline

- Biofiller
- Fuel Pucks (Briquettes) for Greenhouse
  - Heat
  - CO2 (from flue gas)
  - Electricity (1kW microturbine)
- Plastic Composites

- Production Goal: Zero Waste process

Biofillers

- Fillers:
  - >1 um lowering its cost per unit volume
  - < 1um impact modifiers

- Biofillers are used in PP and PVC plastic composite materials:
  - PP (polypropylene) [1]:
    - Ropes, lab equipment
    - Global market volume of 45.1 m mT, US$65b (2008) [2]
    - Up to 75% by weight
    - Typ. Particle size 10 – 60 mesh (2,000 - 180 um)
  - PVC (polyvinyl chloride) [1]:
    - 3rd most widely used plastic: construction materials (sewage pipes)
    - global market volume of 32.3 m mT (2011) [3]
    - Up to 60% by weight, but 20%-40% typ.
    - Typ. particle size: 40-120 mesh (425 - 125um)

Reference:

[1] Juan Bravo - Struktol Company of America, "Engineered Process Additives for the Global Wood-Plastics Composities Market", Nov. 2007 http://www.struktol.com/pdfs/STP0255%20-%20Engineered%20Process%20Additives.pdf

[2] http://en.wikipedia.org/wiki/Polypropylene

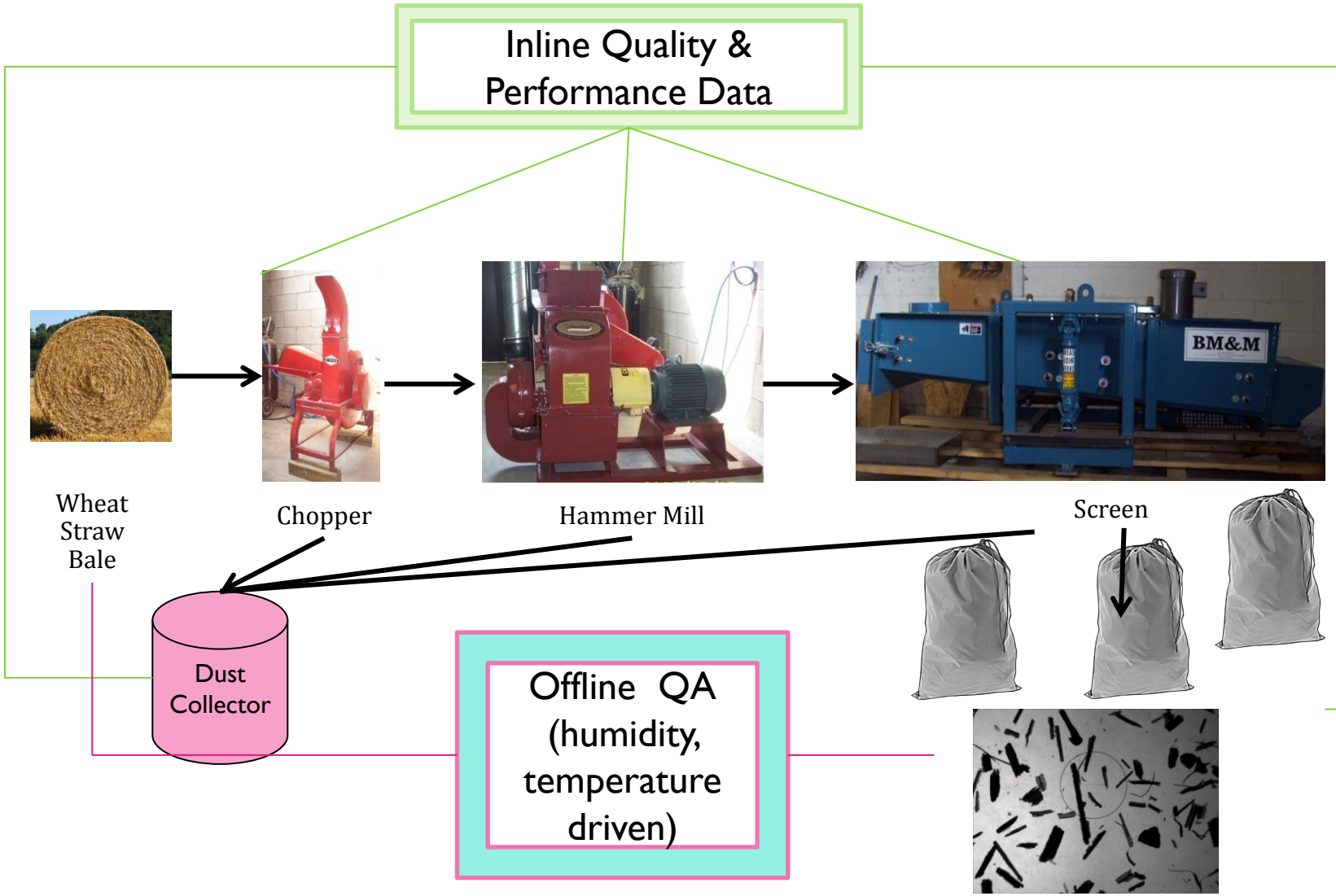
[3] http://www.prnewswire.com/news-releases/pvc-market-demand-continues-to-rise-despite-toxic-dangers-in-everyday-products-167706545.html

OMTEC Biofiller Grades (2013)

Primary products

- WSBF-25 ~1000um avg. particle length
- WSBF-35 ~500um avg. particle length

Biofiller Production



WHEAT STRAW BRIQUETTING

Biomass Combustion - Advantages

- Contributes ~ 14% of global energy supply
- Renewable (annual replenishment cycle): reduction in fossil fuel use
- CO2 reduction/CO2 neutral compared to oil and gas
- Local job employment (50 km)

Lehra LBP 100 Briquettor

Lehra LBP 100

MODEL NO.	PRODUCTION	POWER REQUIRED
LBP 100	2600 kg/h	91 HP

- 4” diameter ram type press
- 75HP main motor

Wheat Straw Briquette

- **Form Factor:**
  - Briquette 90mm (3.75”)diameter
- **Solid Biofuel Standards in EU:**
  - CEN/TC335
- **Advantages of Briquettes over Pellets**
  - Smaller surface to volume ratio of briquette keeps it burning slower (more controlled), and longer

WHEAT STRAW COMBUSTION

Biomass Combustion

- Approx. 14% of world energy is derived from biomass[1]

[1] M. Olsson, "Concentrations of compounds in smoke from wheat straw pellets during the different combustion stages", Biomass and Bioenergy, Volume 30, Issue 6, June 2006, pp. 555–564.http://publications.lib.chalmers.se/records/fulltext/10226.pdf

Biomass Combustion

- **Basic Combustion Equation:**

  something + O2 ---> H2O + CO + CO2

  CO = zero (0) for complete combustion

- **Biomass Combustion Equation:**

  $C\ H_{1.44}\ O_{0.66} + 1.03\ O^2 = 0.72\ H2O + CO2\ (+Heat)$

  - Note: $CH_{1.44}O_{0.66}$ is the approximate chemical equation for the combustible portion of biomass [1]

Reference:

[1] Introduction to Biomass, http://www.extension.org/pages/31758/introduction-to-biomass-combustion

Biomass Combustion

Wheat Straw as a Fuel Feedstock
Small scale 50-250 kBTU/h (15kw-70kw)

sizing, drying, and/or densification

Wheat Straw (Ultimate Analysis)
C – 45.7%
H – 5.7%
O – 43.3%
N – 0.5%
S – 0.3%
Cl – 0.7%

Wheat straw

Storage Risks:
Dust Explosibility.
Self-heating.
Off-gassing.

Legend:

Reagants

Secondary air feed

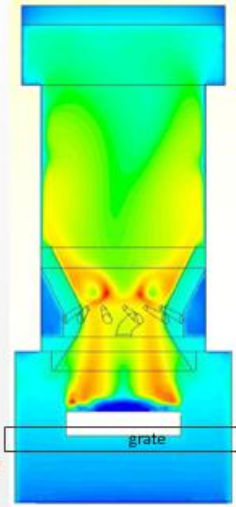
Biomass feed stock (wheat straw)

Burn-back protection

Primary air

Furnace

Flue gas temperatures



Graphic from [5]

Bottom Ash

Flue gas

Solids filter

Gas Filter

Fly ASh

Other waste

CO2 + other stuff

Greenhouse

Heat, Gas, etc.

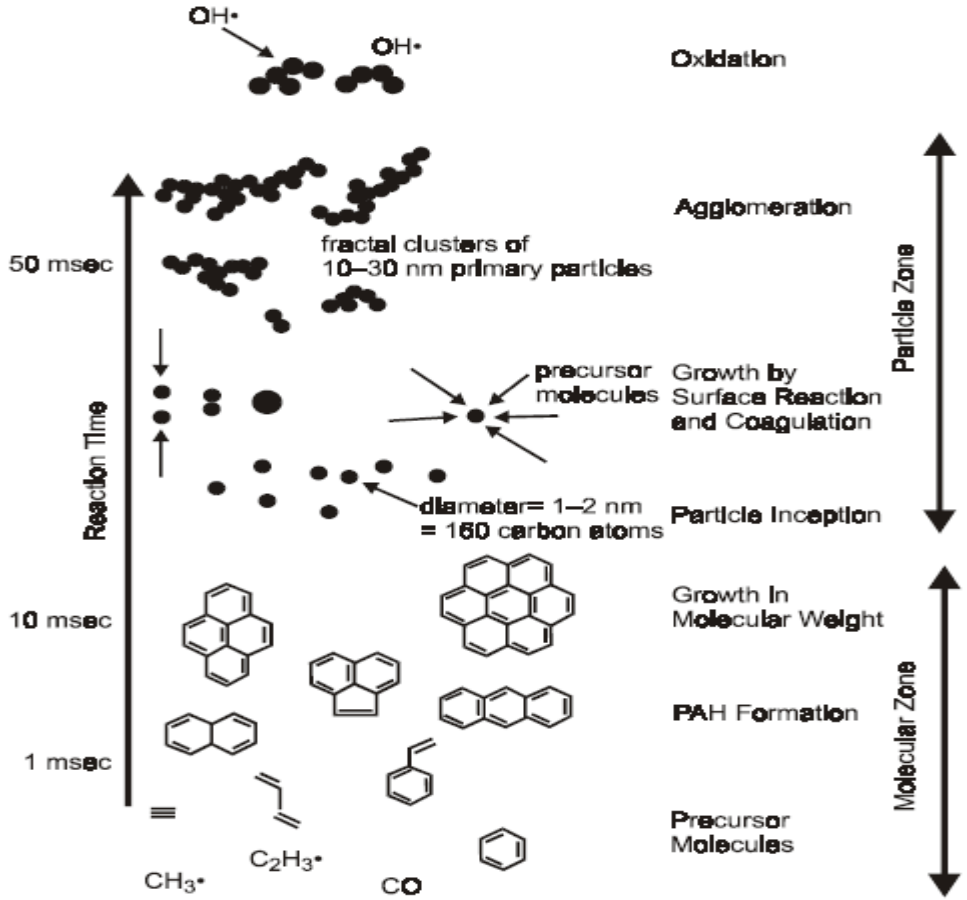
[5] State-of-the-art of small-scale biomass combustion in boilers, http://www.ieabcc.nl/workshops/task32_Dublin_SSC/05%20Obernberger.pdf
Author: Jim Kozlowski, Omtec, Ridgetown, ON
File: OMTEC_biomass_furnace_2013aa.vsd

Biomass Combustion - Temperature Effects

T	Effect	Heat IN/OUT
<1200C	Complete melting	
<1000C	Ash softening points	
700-900C	Sintering temperatures of cereals, eg, wheat straw	
>700C	gasification (H2, CO) [1]	heat IN
>700C	30-75% of chlorine released [2, p.40]	
650-750C	Normal operation of catalytic converter	
500C-700C	Dissociation/carbonization (CO, H2) [1]	heat IN
<500C	25-70% of chlorine is released [2, p. 40]	
280C-500C	Devolatilization (organics, tars, CO2, CO) [1]	**heat OUT**
250C-280C	Torrefaction (Extractives, CO2, CO) [1]	heat IN
230C-250C	Depolymerization (Acetic acid, methanol, CO2, CO) [1]	heat IN
< 200 C	Drying (H2O) [1]	heat IN

References:
[1] Fernando Preto, CanmetENERGY, Natural Resources Canada, Pyrolysis, Char and Energy, 2008, Canmet Energy Canada. http://www.biochar.ca/files/Can%20Biochar%20Initiative%20Preto%20Dec08.pdf
[2] Jennifer Ruth Dodson, "Wheat straw ash and its use as a silica source", Ph.D., thesis, University of York, 2011, http://etheses.whiterose.ac.uk/1931/2/J_Dodson_PhD_thesis.pdf

Schematic picture of soot formation



Source: H. Bockhorn, Soot Formation in Combustion (vol. 59 in Series in Chemical Physics, Springer-Verlag, Berlin, 1994.)

Wheat Straw Briquettes - Ash

Ash Content (wt-%-ash) – Source [1], except where noted.

SiO_2 – 59.9%
Cl – 0.7% (0.7% Ultimate analysis; most in gas phase as HCl) [2]
K_2O – 16.9%
CaO – 7.3%
P_2O_5 – 2.3%
Fe_2O_3 – 0.5%
MgO- 1.8%
Na_2O – 0.4%
Al_2O_3 – 0.8%
Other – 10.1%

Reference:
[1] Hiltunen, M., et al., COMBUSTION OF DIFFERENT TYPES OF BIOMASS IN CFB BOILERS, 2008, http://fwc.com/publications/tech_papers/files/TP_CFB_08_05.pdf
[2] Definition of a standard biomass, 2004 http://www.renew-fuel.com/download.php?dl=del_sp2_wp1_2-1-1_05-01-10-fzk.pdf&kat=14

Wheat Straw Briquettes – Flue Gas

Aerosols from biomass originate from:

- Incomplete combustion (soot)
- Polyaromatic (PAH) hydrocarbons
- Unburnt carbon
- Unburnt biomass fragments

Reference:
Thomas Nussbaumer (Ed.), Aerosols from Biomass Combustion, 200,
http://ieabcc.nl/publications/aerosols.pdf

Wheat Straw Briquettes – Flue Gas

PM10 – Data not known.

PM2.5 – Emission Factors (EFs) from high and low combustion efficiency (CE) wheat stubble burns were 0.8 and 4.7 g/kg, respectively, and decreased with increasing CE [1]

PM1 - alkali transformation causes high emissions of PM1, peaking in the 200um-300um range [2]

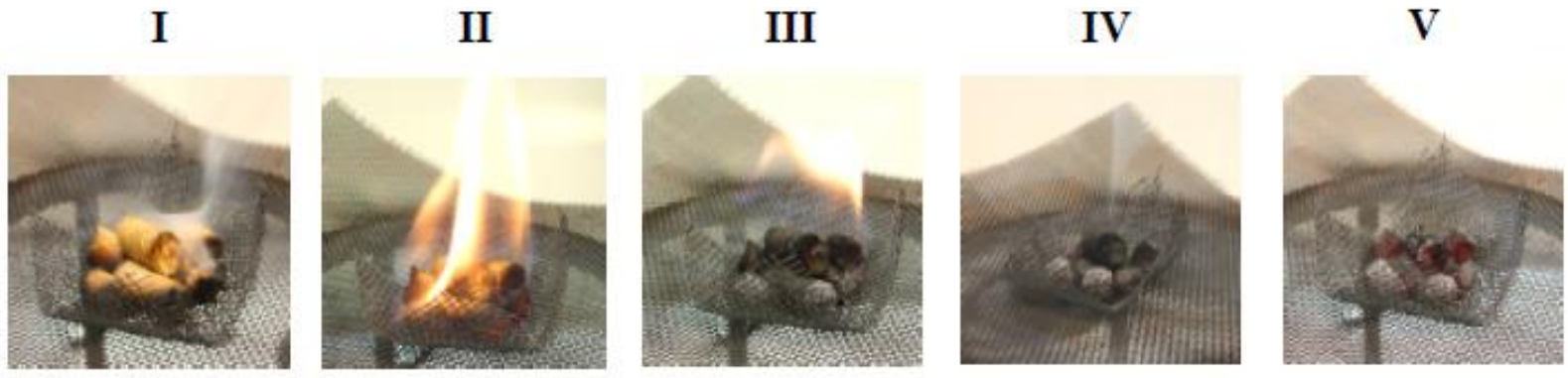
References:
[1] Ranil Dhammapala, Candis Claiborn, Jeff Corkill, Brian Gullett, Particulate emissions from wheat and Kentucky bluegrassstubble burning in eastern Washington and northern Idaho, Atmospheric Environment 40 (2006) 1007–1015
http://www.ag.uidaho.edu/bluegrass/FromJohn/Kentucky%20bluegrass/Emissions/KBG_particulate_emissions.pdf
[2]J Fagerström, I Näzelius, D Boström, M Öhman, C Boman, Reduction of fine particle- and deposit forming alkali by co-combustion ofpeat with wheat straw and forest residues,
http://pure.ltu.se/portal/files/32600648/26._Fagerstr_m_et_al_2010_Imp_of_fuel_quality.pdf"

Wheat Straw Combustion

Gaseous Output

Five (5) sequential phases of combustion, identified which gases concentration varies: [1]

- Initial smouldering (I): Methoxyphenols from the lignin of the fuels released at high concentrations.
- Early flaming (II)
- Late flaming (III)
- After-flame smouldering (IV) : releases high concentrations of compounds that are hazardous to health and the environment (e.g., benzene)
- Final glowing (V)



References:
[1] M. Olsson, "Concentrations of compounds in smoke from wheat straw pellets during the different combustion stages", Biomass and Bioenergy, Volume 30, Issue 6, June 2006, pp. 555–564.http://publications.lib.chalmers.se/records/fulltext/10226.pdf

Wheat Straw Combustion

Flue Gas (Combustion Gas) includes:

- Carbon_dioxide (CO2) - excess CO_2 can also be injurious, with chloroplast disruption and chlorosis often observed above 1000 µmol CO_2 mol^{-1} [2]
- Carbon_monoxide (CO)
- Ethylene (plant hormone, negative effect if in excess)
- Propylene (harmful in greenhouses)
- NOx (mostly due to fuel composition, N 0.5m-% primary micronutrient)
- SOx (mostly due to fuel composition, S 0.3m-% secondary micronutrient)
- Benzene (carcinogenic to humans)
- Methane
- Ethane
- Propane, etc.

References:
[1] M. Olsson, "Concentrations of compounds in smoke from wheat straw pellets during the different combustion stages", Biomass and Bioenergy, Volume 30, Issue 6, June 2006, pp. 555–564.http://publications.lib.chalmers.se/records/fulltext/10226.pdf
[2] Plants in Action, 13.4.1 Greenhouse cropping, http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-4-1-greenhouse-cropping

Wheat Straw Combustion

Combustion Gas	Concentration	Notes
CO2	0.25-0.35 kg/hr/100m2 needed to maintain 1300 ppm (optimum for growing plants.) [1]	Max 5000 ppm if more can cause "dizziness or lack of coordination"; necrosis of old tomato and cucumber leaves. [1]
SO2	0.2ppm cause acute necrosis.	Limestone is often added to the bed material for SO2 capture. [1]
Ethylene	0.05ppm can cause "premature senescence on tomato and cucumber plants"	
CO	Levels > 50ppm CO indicate the presence of ethylene which cause crop damage [1]	Indicator for incomplete combustion. [1]
NOx (incl. NO2)		Caused by high temperature burners. Can diminish grow or cause necrosis. [1] Typically reduced in flue gas by Selective catalytic reduction [1]

Source: [1] OMAFRA, "Carbon Dioxide in Greenhouses" Factsheet, Feb 2012

Summary

- Omtec is developed zero waste production processes for biofiller
- Wheat Straw waste made into 90mm (3.75”) briquettes (5000-7000 BTU/lb)
- Combustion flue gas contains complex mix of gas and solids, but can be filtered to provide CO2 for greenhouses (R&D)
- Ash has some beneficial uses, e.g., cement

Questions?