China Biochar Story:
From crop straw to biomass industry

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Why biochar: SOM depleting lands…

More input, less output?

Chemicals in.

Pesticides in.

Farm energy in...

Pollutants in
Why biochar: straw unrecycled as pollution

Totally 1 Gt, half in northern China
Why biochar: safe recycling in agriculture

- Carbon
  - Nutrient
  - Energy

Deform, transform, reform

Engineering biomass to biochar

Transforming to minimize E-risk

Partitioning to maximize capital
How biochar: Engineering pyrolysis system for agriculture and..

Differentiated pyrolysis, designed products and distributed system of biochar production, 3D approach
Crop straw pyrolyzer, continuous rotatory kiln

30 thousand ton per year feedstock

Developed by Beijing Sanju in cooperation with NJAU
Co-Pyrolyzer: mixed feedstock

Municipal solid waste

Dryer

Kiln

Syngas burner

Feedstock
Designed biochar: single or combined use

<table>
<thead>
<tr>
<th>Biochar Source</th>
<th>SA of biochar (m²/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat straw</td>
<td>16.66</td>
</tr>
<tr>
<td>Maize straw</td>
<td>4.49</td>
</tr>
<tr>
<td>Peanut husk</td>
<td>11.08</td>
</tr>
<tr>
<td>Municipal waste</td>
<td>3.83</td>
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</table>

创新生物质材料:
肥料炭载体、饲料炭载体、吸附剂、钝化剂、食品加工佐剂
创新生物质产品:
纳米盾、炭基肥、土壤改良剂、园艺基质及融雪剂
Designed biochar: from combined feedstock to combined biochar material

Extraction, modification, formulation and granulation...
Main feedstock: straw resource available

Properties concerned:
CEC, SA, pH;
VOMs, porosity;
Ash, ....
Porosity as a key factor: **Cryo-porometry**

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Total ( \text{cm}^3/\text{g} )</th>
<th>Median pore size (nm)</th>
<th>Minimum size (nm)</th>
<th>Size in 95% CI (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rice husk</strong></td>
<td>0.41</td>
<td>80.0</td>
<td>2.0</td>
<td>3.5~250</td>
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<tr>
<td><strong>Maize straw</strong></td>
<td>0.55</td>
<td>50.1</td>
<td>1.2</td>
<td>2-83</td>
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<tr>
<td><strong>Swine manure</strong></td>
<td>0.72</td>
<td>80.0</td>
<td>2.0</td>
<td>15-500</td>
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</table>

**Graphs:**
- **Rice husk biochar**
- **Maize straw biochar**
- **Swine manure biochar**
<table>
<thead>
<tr>
<th>Compounds</th>
<th>Wheat SL</th>
<th>Maize SL</th>
<th>Peanut husk</th>
<th>Wheat LH</th>
<th>Rice husk LH</th>
<th>Rice husk YJ</th>
<th>Maize SX</th>
<th>Wheat TY</th>
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<tr>
<td>2-Butenoic acid</td>
<td>Y</td>
<td>—</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Triethyl phosphate</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Benzenepropanoic acid</td>
<td>—</td>
<td>Y</td>
<td>Y</td>
<td>—</td>
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<tr>
<td>Benozoic acid</td>
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<td>Y</td>
<td>Y</td>
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<td>Y</td>
<td>Y</td>
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<tr>
<td>1-pentene</td>
<td>Y</td>
<td>—</td>
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<tr>
<td>Phenol</td>
<td>Y</td>
<td>Y</td>
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<td>—</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Cyclopentene</td>
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<tr>
<td>Formica acid</td>
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<td>Valeric acid</td>
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<td>Y</td>
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<td>Phthalic acid</td>
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<td>Y</td>
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<td>1,2-Benzendicarboxylic acid</td>
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<td>9,12,15-octadecatrienoic acid</td>
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<td>Y</td>
<td>Y</td>
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<tr>
<td>2-propenoic acid</td>
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<td>Y</td>
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<tr>
<td>n-Hexadecanoic acid</td>
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<td>—</td>
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<tr>
<td>Nicotinic acid</td>
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<td>N-Methylnicotinic acid</td>
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<td>Heptadecanoic acid</td>
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<tr>
<td>Glycerol</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Ribitol</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>1-Hexadecanol</td>
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<td>—</td>
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<td>—</td>
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<tr>
<td>Behenic alcohol</td>
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<td>—</td>
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<td>—</td>
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<tr>
<td>Oleyl alcohol</td>
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<td>Y</td>
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<td>Isoquinoline</td>
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<td>—</td>
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<td>Y</td>
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<tr>
<td>Naphthalene</td>
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<td>—</td>
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<td>—</td>
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<td>—</td>
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<tr>
<td>Urea</td>
<td>—</td>
<td>—</td>
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<td>—</td>
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<td>—</td>
<td>Y</td>
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<tr>
<td>1-Monolinoleoylglycerol trimethylsily ether</td>
<td>Y</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Y</td>
</tr>
</tbody>
</table>

Designed biochar: VOM molecules in biochar ~300 species, DOM 4%, Liquid OM
Biochar industry: Co-production and full use of pyrolysis products

Full chain of multiple products
Core product: Blended biochar compound fertilizer (BCF)
-N-P$_2$O$_5$-K$_2$O, 15-15-10, 40%

organic/inorganic, active Vs structure OM, Habitat and nutrients, macro and micro
BCF 2nd Generation:
balance between org/inorg, N-P-K, major/micro, active/structured OM, quick/slow pool

Simulating aggregates: not only for plants!
2nd BCF: Aggregate-like Compound mineral organo nano-fertilizer
2nd Generation BCF: specifications

Biochar blended compound fertilizers, crop specific

Biochar and liquid combined seedling promotor

Biochar based amendment
Field demonstration in 2017

Overall yield gain: by 8% in previous studies

Mean yield increase by biochar fertilizer
(95% confidence interval)

- Rice: 9.1±1.1%
- Maize: 5.0±6.2%
- Wheat: 10.5±4.3%
- Potato: 22.0±1.15%

Compared to 11% (Jeffery et al., 2011 soil amendment 20t/ha)
Agronomic use efficiency

Improvement of PFPN (95% confidence interval)
- Rice: 13.6±3.8%
- Maize: 47.7±10.8%
- Wheat: 47.3±80.9%

Increase in PFPN correlated to biochar portion in the fertilizer

\[ y = 113.9x + 6.0358 \]
\[ R^2 = 0.441 \]
Table grape at mature

14-08-18
Quality changes *(Table grape)*

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>SPAD</th>
<th>Fruit size (mm)</th>
<th>Sugar (%)</th>
<th>Soluble Prot (mg/g)</th>
<th>Vc (mg/100g)</th>
<th>Acidity (%)</th>
<th>Sugar to acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>38.88 ± 3.40b</td>
<td>21.05 ± 1.22b</td>
<td>17.52 ± 0.13b</td>
<td>56.91 ± 1.18b</td>
<td>3.29 ± 0.12b</td>
<td>0.95 ± 0.02a</td>
<td>18.48 ± 0.31b</td>
</tr>
<tr>
<td>BCF1</td>
<td>40.48 ± 2.85b</td>
<td>24.06 ± 1.26a</td>
<td>18.50 ± 0.12a</td>
<td>60.27 ± 1.52a</td>
<td>4.37 ± 0.35a</td>
<td>0.86 ± 0.03b</td>
<td>21.54 ± 0.82a</td>
</tr>
<tr>
<td>BCF2</td>
<td>43.66 ± 2.72a</td>
<td>23.10 ± 1.27a</td>
<td>18.62 ± 0.04a</td>
<td>60.67 ± 1.08a</td>
<td>4.24 ± 0.19ab</td>
<td>0.87 ± 0.01b</td>
<td>21.34 ± 0.21a</td>
</tr>
</tbody>
</table>

*Improvement: 2-3mm size; 10%, sugar content but 30% for Vc, others improved by 15-20%!*
Main product: **Biochar soil conditioner**

**Soil restoration and rehabilitation**

**Combination, formulation and configuration**
Distributed biomass industry

Pyrolysis

Bioenergy
- Heating
- Vapors
- drying

Biochar-
- solid
- liquid

Nano-
material
- Soil-water
- Food/forage
- Municipal use

Thermolite, transform and segment only
No amendment, no synthesis and no release of chemicals
Distributed system of Biomass-Biochar Industry

Village level

Logistics

County level

- Individual farmers, cooperative farmer groups, feedstock company.
- Biomass Feedstock
- Biochar fertilizer Plant
Feedstock: local collection and processing, sealing to biochar plant via logistics
Government appraised, recognized by extension agency.
Being state policy supported

Low carbon key tech, CRD

"秸秆炭化还田——土壤改良技术", 被国家发改委列入国家重点领域推广的低碳技术目录。

Cutting edge tech, National Chemical Association

“农作物秸秆炭化还田—土壤改良技术开发与应用”被中国石油与化学工业联合会组织专家委员会鉴定为国际领先水平

Recommended as 10 top technique of resource recycling, MoA

Appraised as comprehensive resource cycling industry, MEP

项目背景——符合国家政策方针
China’s state policies regarded to biochar in agriculture

- 2012: Demonstration project of BCF industry, CRD;
- 2013: Key technologies of Low carbon economy, CRD;
- 2015: Extension project by MoA;
- 2017-05: Top 10 Key technologies for recycling straw, MoA;
- 2017-07: BCF standard issued by MoA;
- 2017-11: Co-production of biochar for fertilizer recommended for bioenergy sector, State Energy Bureau;
- 2018-07: Biochar technology as integrated technologies for green agriculture planed by MoA;
- 2018-08: Straw to biochar fertilizer approved as a biomass recycling industry, MEEP;
- more to come up...
Technical advises and services provided for project

- Third-party authoritative institutional test reports: 146 copies.
- Preparation of "2017 Biomass Charcoal Fertilizer Demonstration Field Report Compilation" and "Demonstration Field Construction and Management Manual".
Product standards, operation guideline and quality control protocol available.
Biochar industry:
Linked to local economy development: County

Soil testing and crop straw collection

Localized BCF and integrated fertilization
BCF for special rice in Wuchang County
Biochar industry: linked to Re-vitalization (poverty reduction) in remote rural area

From waste to wealth as from straw to biochar-based agriculture, as in Jianping Liaoning, China
From waste management to food and health improvement!
Integrated soil-plant manipulation technologies under development

- **Land preparation**
  - A Biochar/amendment

- **Seedling/transplantation**
  - B Biochar compound fertilizer

- **Vegetative Growing**
  - C Liquid fertilizer spraying

- **Ripening**
  - D Foliar treatment

Solid to liquid, slow to rapid BCF, large to small application

Soil fertilizty | Plant promotion
Biochar fertilizer based high quality agro-products for special sector: grain for wine
Biochar fertilizer for soybean for food: high yield and quality soybean under testing
Biochar agriculture: cobenefits should not be ignored

On site
• Carbon sequestration
• Grain production
• Household farmers
• Poverty reduction

Off site
• Environmental risks
• Food and health
• Consumers
• Rural vitalization
Biochar for new green agriculture

Government, academic, extension and business in close cooperation