The Mushroom Industry: Overview and Use of Biomass

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World Mushroom Industry
$51 Billion (USD)

- Wild 10%
- Medicinal 31%
- Edible 59%

Chang 1996 & 2013, Li 2012

Outline

- Background on mushroom industry
  - World
  - U.S.
- Six steps to mushroom farming
  - Type and volume of biomass used to produce U.S. mushroom crop
  - Post cropping use of SMS

Chang 2006, 2013
Mushroom Production in Selected Countries (2010)

- China: 20,000 t
- Japan: 500 t
- USA: 500 t
- Netherlands: 500 t
- Poland: 500 t
- Spain: 500 t
- Others EU: 500 t

Yamanaka 2011, Li 2012, FAOSTAT 2013

Cultivated Edible Mushrooms

- Agaricus 30%
- Pleurotus 27%
- Lentinula 17%
- Auricularia 6%
- Flammulina 5%
- Volvariella 5%
- Others 10%

Chang 2006, ISMS 2007, Li 2012

Agaricus Production in Selected Countries (2010)

- China: 20,000 t
- USA: 5,000 t
- Canada: 5,000 t
- Mexico: 5,000 t
- Netherlands: 5,000 t
- Poland: 5,000 t
- Spain: 5,000 t
- Others EU: 5,000 t

Li 2012, FAOSTAT 2013, USDA 2013

United States

- Agaricus 98%
- White 81%
- Brown 17%
- Lentinula 1%

Production

Brown value = 21%

USDA 2013
United States

- Value $1.05 billion
- 3rd largest producer in world – 400,000 T
  - 8% increase from 2010
- Agaricus – Dutch style farms
- 2% Specialties – Shiitake, Pleurotus, Maitake
  - Value 6%

United States

- 62% in Pennsylvania
- 13% California
- 3% organic sales
- 87% sold fresh
- 13% processed
- 19% of growers certified organic

Source: Phillips Mushroom Farms

United States

- Number Agaricus growers decreasing
  -56% in 21 years
- Specialty growers
  -9% in 21 years
- Value
  - Agaricus $1.05 billion
  - Specialties $65 million

Six Steps to Mushroom Farming

1. Phase I Composting
   7-12 d

2. Phase II Composting
   7-14 d

3. Spawning
   12-16 d

4. Casing
   12-14 d

5. Pinning
   4-6 d

6. Cropping
   21-28 d

Royse & Beelman 2013
1. Phase I Composting

- Raw materials
  - Grass hay
  - Wheat straw
  - Corn cobs
  - Cocoa bean hulls
  - Corn stover
  - Straw based stable bedding
- Growers facing shortage of materials

Biomass Used to Produce U.S. *Agaricus* Mushroom Crop

Amount of blended material needed to produce 400,000 tons of harvested mushrooms

<table>
<thead>
<tr>
<th>Stage</th>
<th>Original wt</th>
<th>Conversion (%)</th>
<th>Tons of compost (dry wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production – B.E.</td>
<td>400,000</td>
<td>90</td>
<td>444,000</td>
</tr>
<tr>
<td>At spawning</td>
<td>444,000</td>
<td>115</td>
<td>510,600</td>
</tr>
<tr>
<td>At Phase II composting</td>
<td>510,600</td>
<td>122</td>
<td>623,000</td>
</tr>
<tr>
<td>At Phase I composting</td>
<td>623,000</td>
<td>130</td>
<td>810,000</td>
</tr>
<tr>
<td>Raw material, blended</td>
<td>810,000</td>
<td>118</td>
<td>955,800 (ww)</td>
</tr>
</tbody>
</table>

Shrinkage values: spawn run – 15%; phase II – 22%; phase I – 30%. Average moisture content of blended materials is 18%.

1. Phase I Composting

- Raw materials mixed dry
- Pre-wet period for water absorption
- Windrows for composting

Biomass Used to Produce U.S. *Agaricus* Mushroom Crop

Amount of raw material needed to produce 400,000 tons of harvested mushrooms

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Amount (tons – ww)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass hay</td>
<td>400,000</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>100,000</td>
</tr>
<tr>
<td>Straw-based stable bedding</td>
<td>150,000</td>
</tr>
<tr>
<td>Corn stover</td>
<td>100,000</td>
</tr>
<tr>
<td>Corn cobs</td>
<td>100,000</td>
</tr>
<tr>
<td>Chicken litter</td>
<td>100,000</td>
</tr>
<tr>
<td>Gypsum</td>
<td>21,000</td>
</tr>
</tbody>
</table>
1. Phase I Composting

- Move toward “Bunkers”
- Forced aeration
  - Better conversion
  - Improved mushroom yield
  - Reduced odors
  - Nuisance complaints
- 30% shrinkage of materials

2. Phase II Composting

- Purpose
  - Conditioning
  - Pasteurization
  - Forced aeration and temp control by computer
- In situ – 14 days
- Tunnels (bulk) – 5 to 7 days
  - Reduced loss of biomass
  - Improved mushroom yield
- 22% shrinkage of materials
3. Spawning/Spawn Run

- Spawn
  - Mycelium grown on sterilized grain
  - Millet or rye
- Spawn mixed in with compost and filled into beds or trays
- 14-day spawn run
- 18% shrinkage of compost

5. Pinning

- Mushroom initials “pins” develop on rhizomorphs in casing
- Harvestable mushrooms 18 to 21 days after casing
- Relative humidity and airflow critical for quality mushrooms

4. Casing

- Casing layer necessary for mushroom formation
- Water reservoir for developing mushrooms

6. Cropping

- Harvest 7- to 8-d cycle over 3-4 d
- 3 to 4 flushes/crop
- Mushrooms double in size every 24 h
- Some farms harvest every 8 h
- 90% biological efficiency
Spent Mushroom Compost (SMS)

- Includes casing layer
- 2.7M m³ SMS generated annually in southeast PA
- 45,000 truck loads
- 600 km (SC – Columbus, OH)

Data from 30 mushroom houses (PA)
Fidanza & Beyer (2009)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Dry wt basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>2.7%</td>
</tr>
<tr>
<td>Organic matter</td>
<td>61.0%</td>
</tr>
<tr>
<td>Ash</td>
<td>39.0%</td>
</tr>
<tr>
<td>pH</td>
<td>6.6</td>
</tr>
<tr>
<td>Moisture (57%)</td>
<td></td>
</tr>
</tbody>
</table>

Grass hay = 1-2% N
Poultry manure = 4-5% N
Mycelial biomass = 6.5% N – 5% of total dry wt

- Sports fields
  – Fertilizer
- Soil amendment
- Sustainable cycle
  – Application in spring or fall
  – 1” to 3” depth
  – 130 to 390 yd³ per acre
Spent Mushroom Compost (SMS)

- Horticultural crops
- “Green” roofs
- Mulch – Inhibits artillery fungi

Spent Mushroom Compost (SMS)

- Biofuel
  - Europe
    - Steam, electricity
  - U.S. planning stages
  - Ethanol production

Summary

- 400,000 tons of Agaricus mushrooms produced in U.S. last year valued at $1 billion
- Specialty mushrooms valued at $65 million
- PA #1 producer of mushrooms in U.S. (62%)
- CA #2 (13%)
- 956,000 tons biomass (18% moisture) used to produce the mushroom crop
- Grass hay – main ingredient

More Information

- American Mushroom Institute
  - Production Statistics
  - Related Websites & Documents
  - Contacts
    - Mushroom composters – 7 in PA