

Outline

The Mushroom Industry: Overview and Use of Biomass

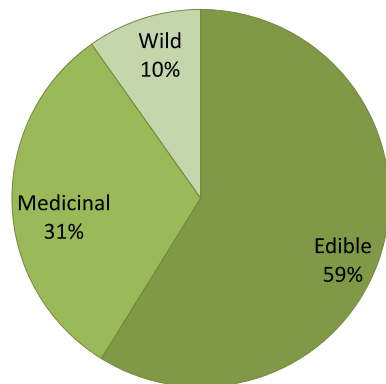
Daniel J. Royse

Plant Pathology and Environmental Microbiology

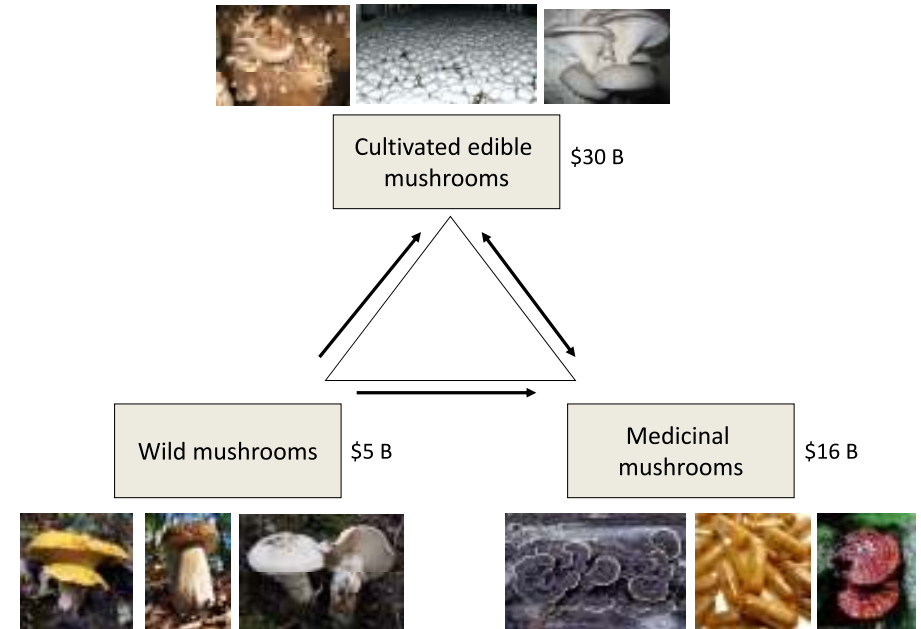


- Background on mushroom industry
 - World
 - U.S.
- Six steps to mushroom farming
 - Type and volume of biomass used to produce U.S. mushroom crop
 - Post cropping use of SMS

World Mushroom Industry \$51 Billion (USD)

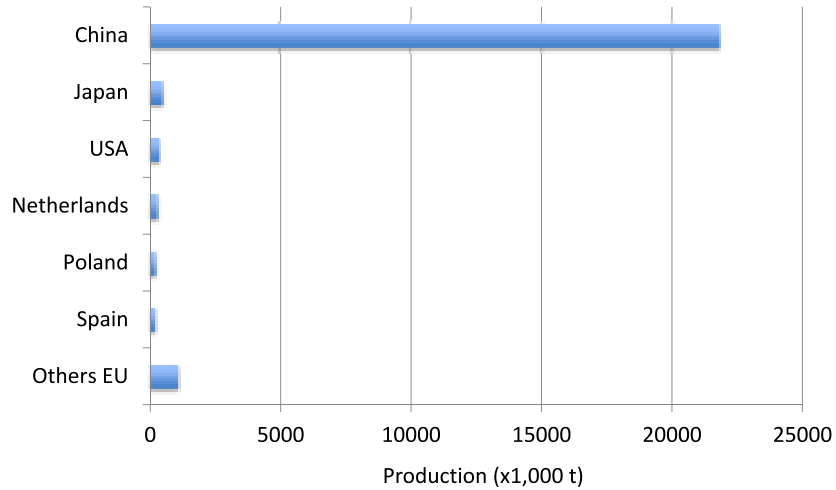


Chang 1996 & 2013, Li 2012



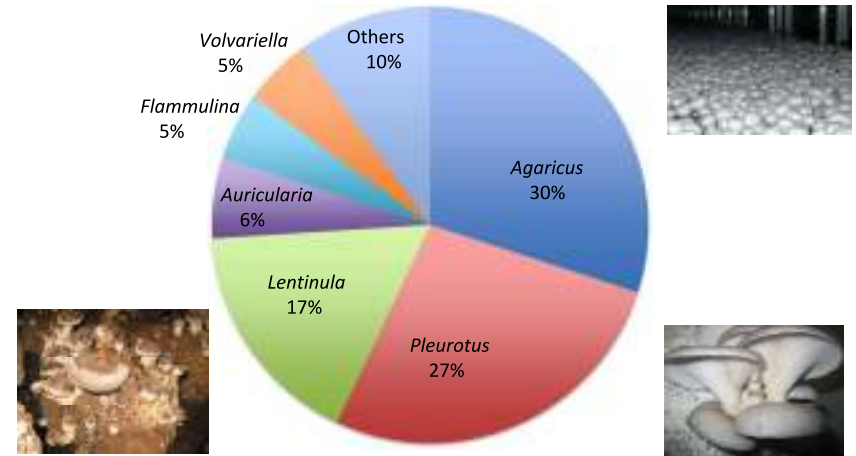
Chang 2006, 2013

Mushroom Production in Selected Countries (2010)



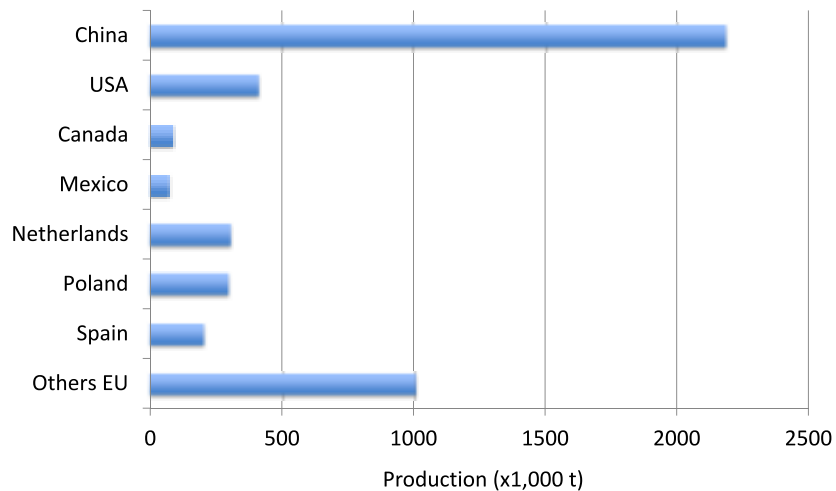
Yamanaka 2011, Li 2012, FAOSTAT 2013

Cultivated Edible Mushrooms



Chang 2006, ISMS 2007, Li 2012

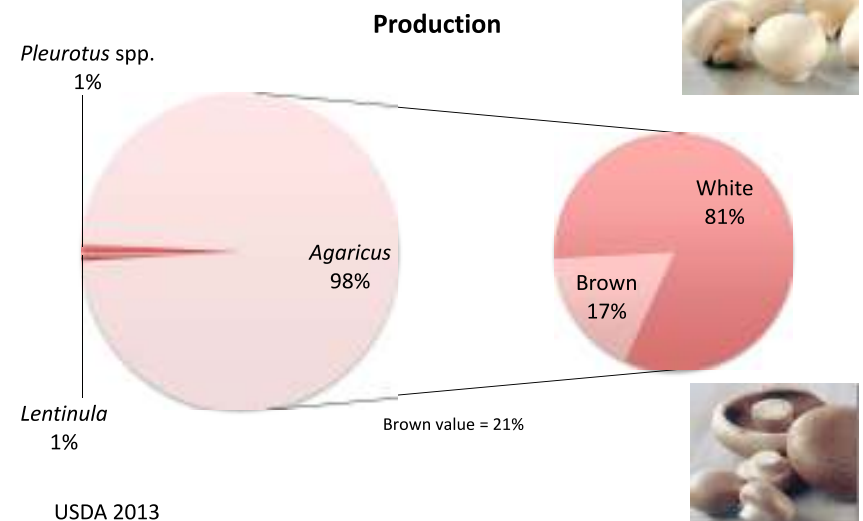
Agaricus Production in Selected Countries (2010)



Li 2012, FAOSTAT 2013, USDA 2013

United States

2012



USDA 2013

United States

2012

- 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

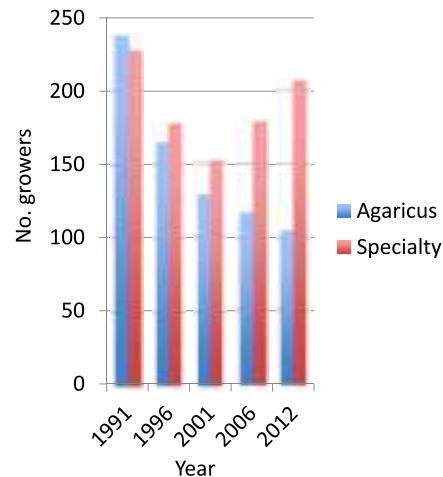
- 62% in Pennsylvania
- 13% California
- 3% organic sales
- 87% sold fresh
- 13% processed
- 19% of growers certified organic



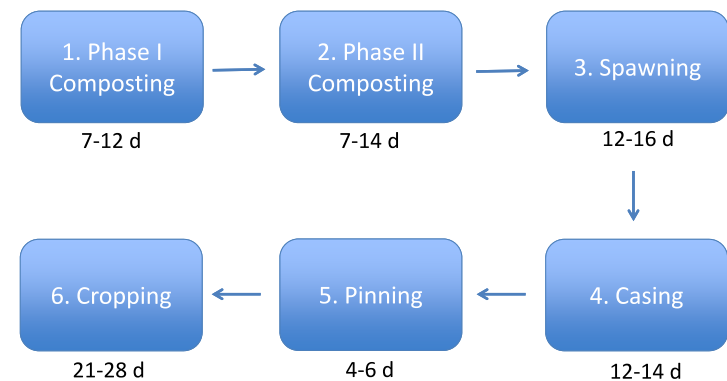
Source: Phillips Mushroom Farms

United States

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



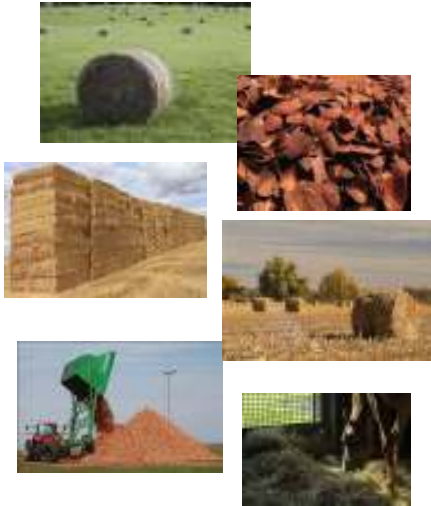
Six Steps to Mushroom Farming



Royse & Beelman 2013

<http://extension.psu.edu/plants/vegetable-fruit/mushrooms/publications/guides/SixSteps.pdf>

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

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

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

Raw Material	Amount (tons – ww)
Grass hay	400,000
Wheat straw	100,000
Straw-based stable bedding	150,000
Corn stover	100,000
Corn cobs	100,000
Chicken litter	100,000
Gypsum	21,000

1. Phase I Composting

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



1. Phase I Composting

- Bio-filters for odor control



1. Phase I Composting

- Totally enclosed bio-filtered facility



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



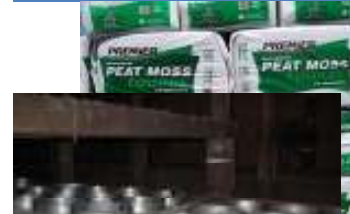
3. Spawning/Spawn Run



- 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



4. Casing



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



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

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)



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)



Spent Mushroom Compost

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

Analyte	Dry wt basis
Nitrogen	2.7%
Organic matter	61.0%
Ash	39.0%
pH	6.6
Moisture (57%)	



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

Spent Mushroom Compost (SMS)



- 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
- <http://www.americanmushroom.org/>
 - Production Statistics
 - Related Websites & Documents
 - Contacts
 - Mushroom composters – 7 in PA