Spawning and Casing Supplements
David M. Beyer, Penn State
Spawning and Casing Supplements

• What is our current understanding of mushroom nutrition?
• What is the purpose of supplementation?
• How many years have gone by without learning anything new about compost and supplementation?
• Today you are going to find out the answers to these and other questions as we discuss mushroom nutrition and supplementation!
“Mushroom substrate has developed from a “hodge-podge” of ingredients mixed with water, fed through a turner and mastered through trial and error”

Dr. Paul Wuest
Questions needed to be asked?

What nutrients does the mushroom need?

What type of carbohydrates does the mushroom use?

What type of nitrogen does the mushroom use?

What else does the mushroom need for food?
Absorption of Food by Fungi

Enzyme Secretion

Insoluble Food Particles

Soluble Food Particles

Absorption

Membrane

Cell wall

Cytoplasm

Vacuole
WHAT NUTRIENTS DOES THE MUSHROOM NEED?

- C (Carbon)
- N (Nitrogen)
- P (Phosphorus)
- F&O (Fertility & Oxygen)
- M (Mycorrhiza)
WHAT NUTRIENTS DOES THE MUSHROOM NEED?

- **Carbohydrates**
  - Simple carbs used by microbes
  - Early Phase I
    - Phase II
  - Complex carbs
    - Formed during Phase I
    - Used after casing
Soluble/Simple Carbohydrates

- Simple carbohydrates used by microbes
  - During composting most soluble sugars used
    - Creates heat
    - Dissolves waxes on the cuticle
  - Luckily these are first carbon sources used
    - Readily digestible sugars the mushroom can but would not use

Microbes

What remains
Complex Carbohydrates

More complex carbohydrates

- Few microbes have ability to dissolve cellulose
- Complex sugars are only used by mushroom
- Formed by linking together the simple sugars
  - Cellulose and hemicellulose
- Carbohydrates are changed during composting
BROWNING REACTIONS

- **Carmelization**
  - Sugars → Brown Pigments + H20
  - High Temps + NH3

- **Maillard Reaction**
  - Reducing sugars + N-amines → Brown Pigments
  - High Temps + NH3

- **Pyrolysis**
  - Sugars → Brown/Black Pigments
  - Extremely High Temperatures
  - No Oxygen

- **Enzymatic Browning**
  - Phenolics → Brown Pigments
  - Polyphenol oxidase enzymes
  - No Oxygen
Carmelization
(Darkening of Straw)

- At higher temperatures carmelization takes place.
- Water eliminated from carbohydrates concentrates carbon.
- Carbon now more available to only the mushroom.
- Ammonia and high temperatures speed this process.

Chemical Reactions:

$$\text{NH}_3 + \text{Heat} \rightarrow \text{Caramelization}$$
WHAT NUTRIENTS DOES THE MUSHROOM NEED?

C

N

P

F&O

M
Sugars Become Exhausted During Composting

- When sugars (simple carbs) are used up
  - Complex carbohydrates are left
    - Hemicellulose, cellulose and lignin
  - Except for lignin
    - Lignin becomes dominant
Lignin-Nitrogen Complex

- Formed during Phase I composting
- Used during Phase III spawn run
Throughout Phase I and II
- Lignin concentration remains the same

Lignin relatively untouched by microbes
- Most microbes lack enzyme to dissolve it
- But it is chemically altered

Lignin is also hydrophobic
- Influences WHC
Lignin-Nitrogen Complex

Microbial Degradation
- Disrupts lignin molecule reacts with Nitrogen
  - Forms the dark colored humic substance
- Ammonia creates stable adsorption of nitrogen to lignin
  - N content increases with treatment length

Reaction occurs more rapidly with:
- Higher temperatures
- Higher ammonia concentrations
NITROGEN DURING PHASE I

- Change in type (quality) and quantity of N
  - Nitrogen combines with lignin
  - Ammonification
    - Ammonia ($\text{NH}_3$)
      - Important for chemical reactions
      - Gas lost in the air
    - Ammonium salts
    - Phase II microbial food
WHAT NUTRIENTS DOES THE MUSHROOM NEED?

C
N
P
F&O
M
Proteins

- Found in Phase II microbial biomass
- From Spawn/case supplements
- Used during spawn run (and later)?
WHAT NUTRIENTS DOES THE MUSHROOM NEED?

- **Fats and Oils (Lipids)**
  - Influence
    - Rate and “quantity” of spawn growth
    - Stimulate pinning
  - Sources
    - Phase II Microbial Biomass
      - Packages to deliver protein and fat
    - *Scyltidium thermophilum*
    - Spawn/case supplements
WHAT NUTRIENTS DOES THE MUSHROOM NEED?

- **Micronutrients**
  - Phosphorus, Selenium, Boron, Manganese
    - Phase I and Phase II
    - Added to Spawn/case supplements
Mushroom has adapted a system to use lignin, complex carbohydrates, proteins and lipids in a low soluble carbohydrate system.
NUTRIENT INTERACTIONS INVOLVED IN MUSHROOM CELL SYNTHESIS

Glucose + Enzymes = Mannitol Fruit Bodies

Fatty Acids + Enzymes and Acetate = Fatty Acids

Mannitol Fruit Bodies + Chitin Cell Wall = Ergosterol

Proteins + Amino Acids = Cellular Protein

NUTRIENT INTERACTIONS INVOLVED IN MUSHROOM CELL SYNTHESIS

Glucose

Enzymes

Mannitol Fruit Bodies

Chitin Cell Wall

Fatty Acids

Enzymes and Acetate

Fatty Acids

Ergosterol

Proteins

Lignin-N

Amino Acids

Cellular Protein
Nutrient Transport

Physiological Mechanism

- Protoplastm accumulates in spawn (compost) before fruiting
Protoplasm Ooze

Protoplasm oozes up through rhizomorphs to form tissue or expand cells in the rapidly developing mushroom

- Compost nutrition and spawn metabolism is the “PUMP”
- Casing “PIPES” need to be effectively working – stress free
Questions needed to be asked?

• Does compost quality have any relationship to supplement performance?
• Do supplements improve poor compost performance?
• Why do we use supplements?
What needs to be optimized in compost to achieve maximum mushroom yield and fresh quality from supplements?

Does compost quality have any relationship to supplement performance?
WHAT NEEDS TO BE OPTIMIZE IN COMPOST TO ACHIEVE MAXIMUM MUSHROOM YIELD AND FRESH QUALITY FROM SUPPLEMENTS?

- **Compost Selectivity**
  - Creating a mushroom niche
  - One reason composting is necessary
What needs to be optimize in compost to achieve maximum mushroom yield and fresh quality from supplements?
WHAT NEEDS TO BE OPTIMIZE IN COMPOST TO ACHIEVE MAXIMUM MUSHROOM YIELD AND FRESH QUALITY FROM SUPPLEMENTS?

- **Compost Moisture**
  - Key component for mushroom quality and yields
What needs to be optimize in compost to achieve maximum mushroom yield and fresh quality from supplements?
WHAT NEEDS TO BE OPTIMIZE IN COMPOST TO ACHIEVE MAXIMUM MUSHROOM YIELD AND FRESH QUALITY FROM SUPPLEMENTS?

• Compost Nutrition
  – Spawn growth vigor and metabolism
  – High lipid/protein ratio in compost
• Indicates good yield potential
COMPOST SUPPLEMENTATION

- Protein Content
  - Isoleucine an amino acid
- Lipid (Fats/Oils) Content
  - Affects both rate and quantity of growth
  - Affects pinning
- Micronutrients
  - Phosphorus, Selenium, Boron
- Microbial – Adding Phase II compost
  - Other?
• How did supplements develop over time?
• What kinds of supplements are there?
DEVELOPMENT OF SUPPLEMENTS

- Sinden – Schisler (1960 – 1972)
  - Increase yield whole seeds added at casing
  - Meals little increase in yields
  - Oils added more increase yields
## Yield Response to Timing of Supplement Addition

<table>
<thead>
<tr>
<th>Supplement</th>
<th>% Increase</th>
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<tbody>
<tr>
<td><strong>At Spawning</strong></td>
<td></td>
</tr>
<tr>
<td>Cotton Seed Meal</td>
<td>+22</td>
</tr>
<tr>
<td>Soybean Meal</td>
<td>+24</td>
</tr>
<tr>
<td>Corn Gluten</td>
<td>+23</td>
</tr>
<tr>
<td>Skim Milk</td>
<td>+11</td>
</tr>
<tr>
<td>Hydrolyzed Vegetable Protein</td>
<td>+18</td>
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<tr>
<td><strong>At Casing</strong></td>
<td></td>
</tr>
<tr>
<td>Cotton Seed Meal</td>
<td>+49</td>
</tr>
<tr>
<td>Soybean Meal</td>
<td>+51</td>
</tr>
<tr>
<td>Corn Gluten</td>
<td>+33</td>
</tr>
<tr>
<td>Brewers Grain</td>
<td>+51</td>
</tr>
<tr>
<td>Hydrolyzed Vegetable Protein</td>
<td>+78</td>
</tr>
</tbody>
</table>

Sinden and Schisler, 1962
## DIFFERENT SUPPLEMENTS AT CASING

<table>
<thead>
<tr>
<th>Supplement</th>
<th>% Protein</th>
<th>Yield (lbs/sq.ft.)</th>
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<tbody>
<tr>
<td>None</td>
<td>-</td>
<td>2.52</td>
</tr>
<tr>
<td>Cotton seed meal</td>
<td>42.7</td>
<td>3.13</td>
</tr>
<tr>
<td>Ground cotton seeds</td>
<td>22.9</td>
<td>3.68</td>
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<tr>
<td>Peanut meal</td>
<td>45.0</td>
<td>3.14</td>
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<tr>
<td>Ground peanuts</td>
<td>29.2</td>
<td>3.86</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>45.4</td>
<td>3.07</td>
</tr>
<tr>
<td>Ground soybeans</td>
<td>36.6</td>
<td>3.41</td>
</tr>
</tbody>
</table>

Adapted from Schisler, 1972
<table>
<thead>
<tr>
<th>Supplement</th>
<th>Amt. Added</th>
<th>Yield (lbs/sq.ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0 g</td>
<td>3.63</td>
</tr>
<tr>
<td>CS Meal</td>
<td>500 g</td>
<td>4.06</td>
</tr>
<tr>
<td>CS Oil</td>
<td>400 ml</td>
<td>4.56</td>
</tr>
<tr>
<td>CS Meal + Oil</td>
<td>500 + 400 ml</td>
<td>5.18</td>
</tr>
</tbody>
</table>

Schisler, 1972
LIPID METABOLISM AND FRUITING

- Yield increases with vegetable oils
  - **Not** Mushroom Size, but..... More Pins
- Lipids are a “Pinning Stimulator”
  - Spawn grains (rye, millet, wheat)
  - Hay has enough lipid to improve yield
- Metabolic pathway to produce Mannitol
• Synthesized in the mushroom fruit bodies
  • Not found in the mycelium
• Increase Mannitol concentration
  • Osmotic gradient
    • Low levels in compost
    • High levels in mushroom fruit bodies
    • Encourages flow of water thru rhizomorphs
Function of Mannitol

All food/ most water comes from compost

“Half of the food and water for half the break’s yield is moved to and supplied to the mushroom in one day”
DEVELOPMENT OF SUPPLEMENTS

- Schisler & Carroll – Delayed Release Nutrient
  - Need to develop oil delivery system for bed farm growers
  - Develop a packet of oils and lipids for mushroom
    - Not readily available to other competitors
  - Denatured protein cottonseed, soybean, and peanuts
TYPES

- No delay
  - Grounds seeds – CAC only
- Slight delay
  - Early heat surge – less forgiving
- Delayed release
  - Later heat surge – more forgiving
- Protein-Fat Content
  - Low protein – Low fat
  - Medium protein – Low fat
  - Medium protein – High fat
  - High protein – Low fat
SUPPLEMENT QUAD

<table>
<thead>
<tr>
<th>More Forgiving</th>
<th>Less Forgiving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Protein Low Fat</td>
<td>High Protein Low Fat</td>
</tr>
<tr>
<td>Medium Protein High Fat</td>
<td>Medium Protein Low Fat</td>
</tr>
</tbody>
</table>

Source: adapted from Wach and Wheeler, 1998
Are all supplements suited to all growing operations?
How to Choose the Right Supplement?
What Supplement Rate to Use?
Which Supplement to Use?
CHOOSING THE RIGHT SUPPLEMENT

• Different compost – different supplement
  • Protein enhanced compost normally yield higher
• Compost quality
  • Makes a good compost better
  • Does not make a bad compost better
    • Sometime makes it worst
• Spawning or casing
  • More “protected” delayed needed for spawning
    • > $$$$  
  • Less “protected” for casing
    • < $$$$$
WHICH SUPPLEMENT TO USE?

- Compost quality
  - Moisture and conditioning
- Farm design and air handling capacity
  - Cooling and fan capacity
- Mixing equipment
  - Uniform mixing critical
- Ease of use
  - Type and timing of nutrient release
- Grower experience
  - Anticipation of heat surge
SUPPLEMENT RATES USED AT SPAWNING

% Protein
% Dry weight
What role does microbes play in mushroom nutrition?
Traditional compost supported more fungal diversity during Phase I. Fungal profiles were similar between composting methods at end of Phase II. *Scytdalidium thermophilum* was the dominant compost mold.

- All fungal strains, except *Scytdalidium*, have not been previously reported...
- Commercial mushroom compost contains many *New* uncharacterized fungi.

K. Ivors, PSU 2000
SCYTALEIDUM THERMOPHILUM

- During Phase II thermophilic fungus *Scytaledium* becomes abundant
  - Correlated with mushroom yield
  - Stimulates mycelium growth rate
  - Added to pasteurized compost as a “supplement” increases yield
  - Important for conversion straw to compost
  - Catalase enzyme catalyzes hydrogen peroxide (H$_2$O$_2$) into H$_2$O and O$_2$

*Straatsma, et al* 1994
QUESTIONS NEEDED TO BE ASKED?

Problems associated with supplements?
PROBLEMS

• Poor quality ingredients
  • Contaminated with pests and molds
• Increased metabolic activity requires additional cooling and anticipation
• Surface molds
  • Nuisance and reduces the food for mushroom
• Supplement added at casing results in higher yields than when added at spawning
  • Nutrients readily available directly to spawn
  • No competitors
  • Increased heat production – additional cooling capacity and management
  • Casing management adjusted
What supplement research needs to be done?
• Compost supplies carbohydrates, lignin-N and microbial fats and oils
• Supplements provide protein and fats/oils directly for the spawn
  – Important for nutrition and mannitol synthesis
• Type used depends on?

Your Farm!

“Correlated with Compost Quality”
Thank You!
David M. Beyer
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You’re Invited

56th Mushroom Short Course
September 28-30th 2014
Kennett Square, PA
http://agsci.psu.edu/mushroom-conference