Rapid Vitamin D Enhancement in Mushrooms Using Pulsed UV Light

51st Annual Penn State Mushroom Industry Conference
Sept 20-22, 2009
Presentation Overview

- The Nutritional Value of Vitamin D
- Mushroom Vitamin D Research
- Understanding Pulsed UV Light
- Future Pulsed Light Advances
- Acknowledgements
Vitamin D – the “Nutrient of the Decade?”

- Vitamin D, known as the “sunshine vitamin”
- Vitamin D has been found to:
  - Strengthen bones
  - Reduce tumor growth
  - Lower your risk of cancer
  - Reduce your risk of multiple sclerosis
  - Lower your risk of diabetes
- New studies continue to highlight vitamin D benefits

Study identifies vitamin D’s benefits for diabetic heart health
Nutra Ingredients.com; Stephen Daniells, 24-Aug-2009
Is there a health problem?

Low consumption of vitamin D is a concern

Breaking News on Supplements & Nutrition - North America

Be aware of vitamin D insufficiency, says US Dermatology Academy
By Lorraine Heller, 16-Jul-2009

This situation creates the opportunity to increase consumption of mushrooms Worldwide
Mushrooms as a Source of Vitamin D

- Mushrooms are the only non-animal food that can provide Vitamin D
  - Cultivated mushrooms unexposed to UV light do not provide vitamin D
  - Mushrooms have relatively high levels of ergosterol - when exposed to UV light is converted to ergocalciferol (known as vitamin D$_2$)

- A study performed by the United States Department of Agriculture demonstrated how continuous UV exposure can accelerate vitamin D in mushrooms – achieving levels > 100% DV in 8 minutes of exposure time.

- A study performed by The Pennsylvania State University, using pulsed UV light, demonstrated that vitamin D can be increased >100% DV in under 1 second.
Monterey Mushrooms touts vitamin D benefits

“We’re challenging people to get more vitamin D and get their levels up,” said vice president of biotech and product development John Kidder.
Dole Mushrooms pack a vitamin D boost

“To boost the natural value of vitamin D in the mushrooms, the company exposes them to an intense burst of light similar to that of a camera flash for less than a second, said Gary Schroeder, director of Dole Mushrooms and president of Oakshire Mushroom Farm Inc., Kennett Square, Pa., which supplies Dole-brand mushrooms.”
Can Vitamin D Mushrooms Create Consumer Interest?

Consider what Good Housekeeping magazine has to say!

First Annual VIP (Very Innovative Products) Awards

Thousands of products are reviewed in GHRI's labs each year. Many are problem-solving. Many perform well. And quite a few are innovative. But the winners of GH's First Annual VIP (Very Innovative Products) Awards meet all three criteria.

Portobello Mushrooms

Most of us don't get enough vitamin D — a real concern, because low levels are linked to cancer, heart disease, high blood pressure, and diabetes. What's more, very few foods provide much of the nutrient. Enter Dole's Portobello mushroom caps and slices: One package contains 800 IUs of D, the daily amount experts suggest. The secret is a simple flash of light during the growth process, which helps the mushrooms synthesize more D, without changing the taste. $3.50 for six ounces, Dole; major supermarkets
How did the mushroom industry get to this point?

There has been a growing number of research studies investigating how ultraviolet treatment of fresh mushrooms increases vitamin D2

Light-zapped mushrooms filled with vitamin D
Bringing 'shrooms out of the dark packs them with sunshine nutrient

Associated Press
Tues., April 18, 2006
Research Studies –
Mushroom + UV Exposure = Vitamin D

- Roberts, J. S., Teichert, A., McHugh, T. H. (2008). Journal of Agriculture and Food Science, Vitamin D2 Formation From Post-Harvest UV-B Treatment of Mushrooms (Agaricus bisporus) and Retention During Storage
- Beelman, R. (2008). Mushroom Short Course; Mushroom Nutritional Research; Dr. Robert Beelman Professor of Food Science, The Pennsylvania State University
- Beelman, R.B. and Kalaras, M.D. (2008). Vitamin D2 Enrichment In Fresh Mushrooms Using Pulsed UV Light
- Williams, R. (2009). Installing a Vitamin D System for Pulsed Light Treatment of Mushrooms; Xenon Corporation
Focus of research

- What amount of vitamin D increase is achieved?
- Does the UV intensity influence the level of vitamin D?
- Is there a reduction in vitamin D during an 8-day shelf life?
- Does the color of the mushroom change?
- Is there any difference when mushrooms are washed or sliced?
- What is the added cost to treat mushrooms in a commercial installation?
- Is there a temperature rise during exposure?
- Can different types of mushrooms be treated?
- Is there any difference in vitamin D levels for different mushrooms?
UV Delivery Methods

- Initial studies done with mercury UV-B lamps
- Increasing number of studies being done with xenon pulsed UV light lamps

- Penn State - USA (studies in 2008 and 2009)
- Xenon Corp (study in 2008)
- Australian Mushroom Growers Association (2009)
### Pulsed UV Light Treatment of Mushrooms at Xenon Corp

<table>
<thead>
<tr>
<th>Sample</th>
<th>Weight (Lbs)</th>
<th>Temperature (Deg F)</th>
<th>Sample Type</th>
<th>Lamp Diameter (inches)</th>
<th>Orientation</th>
<th>Energy (Joules)</th>
<th>Distance (inches)</th>
<th>Lamp Type</th>
<th>System Requirement</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.24</td>
<td>71</td>
<td>2.2</td>
<td>Top Up</td>
<td>1.25</td>
<td>C</td>
<td>1.12</td>
<td>1.12</td>
<td>0.0319</td>
<td>0.0319</td>
<td>184</td>
</tr>
<tr>
<td>0.278</td>
<td>70</td>
<td>2.3</td>
<td>Top Up</td>
<td>1.25</td>
<td>C</td>
<td>2.24</td>
<td>0.0638</td>
<td>383</td>
<td>191.5</td>
<td>138.5</td>
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<tr>
<td>0.268</td>
<td>71</td>
<td>2.17</td>
<td>Top Up</td>
<td>1.25</td>
<td>C</td>
<td>3.36</td>
<td>0.0957</td>
<td>374</td>
<td>125</td>
<td>114.1</td>
</tr>
<tr>
<td>0.241</td>
<td>71</td>
<td>2.12</td>
<td>Top Up</td>
<td>1.25</td>
<td>B</td>
<td>0.873</td>
<td>1.746</td>
<td>0.0343</td>
<td>0.0686</td>
<td>1410</td>
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<tr>
<td>0.228</td>
<td>70</td>
<td>2.11</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>20.7</td>
</tr>
</tbody>
</table>
Results from tests performed at Xenon Corp’s lab in Wilmington, MA

<table>
<thead>
<tr>
<th>No Exposure - control</th>
<th>IU</th>
<th>% DV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portabella control</td>
<td>30</td>
<td>8%</td>
</tr>
<tr>
<td>Sliced White Whole control</td>
<td>20</td>
<td>5%</td>
</tr>
<tr>
<td>Portabella</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-pulse</td>
<td>285</td>
<td>71%</td>
</tr>
<tr>
<td>2-pulses</td>
<td>554</td>
<td>139%</td>
</tr>
<tr>
<td>3-pulses</td>
<td>456</td>
<td>114%</td>
</tr>
<tr>
<td>Sliced White Whole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-pulse</td>
<td>734</td>
<td>183%</td>
</tr>
</tbody>
</table>
| 2-pulses                        | 2106| 526% |}

As few as 2-pulses, applied in less than 1-second produced vitamin D >100% DV in fresh mushrooms
Study on White Button, Brown Button, Shiitake and Oyster Mushrooms

Results from tests performed at Penn State, Dept of Food Science

<table>
<thead>
<tr>
<th>Mushroom Type</th>
<th>Number of Pulses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>White Button (Agaricus bisporus)</td>
<td>0%</td>
</tr>
<tr>
<td>Brown Button (Agaricus bisporus)</td>
<td>4%</td>
</tr>
<tr>
<td>Shiitake (Lentinula edodes)</td>
<td>3%</td>
</tr>
<tr>
<td>Oyster (Pleurotus ostreatus)</td>
<td>15%</td>
</tr>
</tbody>
</table>

Notes
1 - *100% Daily Value (DV) = 400 IU
2 - Pulse rate = 3 pulses/second; Xenon Corp "B" Lamp; 505 Joules/pulse
3 - Mushroom top placed 1.25” below quartz window, 16” Lamp Housing
4 - Study performed by M. Kalaras and R. Beelman, Dept of Food Science, Penn State University

1-pulse, applied in under 1-sec increased vitamin D$_2$ to over 100% DV in one serving fresh mushrooms
Pulsed UV Light Equipment

Lamp Housing with Flashlamp

Controller

Lamp Housing Blower
The Basics of Pulsed Light
High Peak Power Low Average Power

Peak vs. Average Power

1.8 MW Peak Power
320 µs

Average Power 1.5 kW

333 ms

Time
Pulsed light more closely matches the spectrum of natural sunlight
UV-B (Mercury) Lamp
- ‘line’ spectra

Mercury Arc Lamp Spectra is not continuous like the Sun spectra

Zeiss-Campus, Fundamentals of Mercury Arc Lamps
The Heart of a Pulsed Light System

- Controlled airflow for cool operation
- Optical reflector for uniform footprint
- Heat sink sockets for long lamp life
- U Lamp for maximum peak intensity
Integrating Pulsed Light into an Inline Processing system

- **Step 1** – Review installation guidelines¹ with Xenon
- **Step 2** – Design a light blocking tunnel to fit over mushroom conveyor belt
  - Pulsed light is very bright – must be shielded from operator eyes
  - We can recommend experienced integrator to help but have found most growers can do this work
- **Step 3** – Confirm actual vitamin D level
- **Step 4** – Establish routine verification and maintenance schedules

¹ Williams, R. (2009). Installing a Vitamin D System for Pulsed Light Treatment of Mushrooms; Xenon Corporation
Designing Light Blocking Tunnel Over Conveyor Belt

- 16" LAMP HOUSING
- 14.00
- Customer's Typical 12" Conveyor
- 16" LAMP HOUSING
- Free Standing Light Blocking Clam Shell Shroud
- 3.50
- 60.00
- 16" LAMP HOUSING
- 7.50
- 47.00
- 7.00
- 30.00
- 16.00
- 18.00

XENON
Variables that control the level of vitamin D delivered

- Variety of mushroom
  - oyster, portabella, white button, shiitake...
- Mushroom size
- Position below lamp housing window
- Position of lamp housing over conveyor
- Speed of conveyor belt

Designing a system using Pulsed UV Light system, can address all variables and result in a reliable, repeatable, inline process at grower facilities.
## Pulsed UV Lamp vs. Mercury Lamp – for vitamin D enhancement

<table>
<thead>
<tr>
<th></th>
<th>Pulsed Light System</th>
<th>Mercury Lamp System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectra</td>
<td>Close to Sunlight</td>
<td>Line Spectra</td>
</tr>
<tr>
<td>Heat</td>
<td>Minimal IR</td>
<td>Significant IR</td>
</tr>
<tr>
<td>Personnel Safety</td>
<td>Risk Eliminated</td>
<td>Mercury (Hg)</td>
</tr>
<tr>
<td>Environmentally Friendly</td>
<td>No Hg &amp; Less Energy</td>
<td>Hg and More Energy</td>
</tr>
</tbody>
</table>
Future Advances
Longer lamps

Increase the optical footprint
16-inch lamp > 30-inch lamp > ?
Future Advances
New Lamps and Optical Designs

U-lamp widens the optical footprint
Future Advances
InterWeave™ Technology

- Less hardware
  - Less cost
- Simplified controls
- Handle multiple conveyor lines
- Increased mushroom output
Acknowledgements

Xenon Corporation wishes to acknowledge the many contributions of:

- Dr. Robert Beelman - Penn State University
- Laura Phelps - American Mushroom Institute
- Bart Minor - American Mushroom Council
- Jack Cook - American Mushroom Cooperative
- Australian Mushroom Growers of Australia
- Mushroom Growers Worldwide
  - USA
  - Canada
  - South America
  - Mexico
  - Ireland
THE POWER OF THE SUN