This article lists the information and resources needed to meet Good Agricultural Practices (GAPs) and Food Safety Modernization Act (FSMA) standards specific for the mushroom industry.

**Good Agricultural Practices Audit Resources**

Mushroom Good Agricultural Practices (MGAP) are commodity specific food safety standards for growing of mushrooms. Information on MGAP standards, and commercial and USDA audit systems that have adopted the standards, can be found on the American Mushroom Institute website.

**The USDA MGAP Audit**

The USDA Agricultural Marketing Service is one audit program available to mushroom growers. Commodity specific guidance for this audit program was provided by the American Mushroom Institute and Penn State University within the "Industry-Wide Food Safety Standards for Fresh Mushroom Growing, Harvesting, and Shipping on the USDA Commodity Specific Audit Programs" website.

**FSMA and Mushroom Food Safety Resources**

**For Inspectors, Auditors, and Visitors to Mushroom Farms**

*Basic Procedures for Agaricus Mushroom Growing.* Beyer, D. M.

Commercial mushroom growing requires specialized facilities and procedures for successful composting and cultivation. Knowledge of potential food safety risks during mushroom growing requires an understanding of the mushroom growing process.

**For Commercial Mushroom Growers, Packers, and Shippers**


In this article, farming activities and types of produce that are covered, key requirements, possible exemptions, and deadlines for compliance within the Food Safety Modernization Act (FSMA) Produce Safety Rule are discussed.


The FSMA Preventive Controls for Human Food regulation requires processors to consider the potential for cross-contamination of equipment during operation and develop sanitation preventive controls proven to minimize risks. Fresh-cut produce operations are especially warned to be aware of the potential for mechanical slicers to harbor and ultimately transfer *L. monocytogenes* to ready-to-eat produce products. This article summarizes a Penn State research project to validate a hot water immersion method for elimination of *L. monocytogenes* from mushrooms disk slicers.


The mushroom industry will be impacted by two of the FSMA regulations, "Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption" (Produce Safety Rule) and "Current Good Manufacturing Practice and Hazard Analysis and Risk-Based Preventive Controls for Human Food" (Preventive Controls Rule). How these may impact mushroom growing and packing operations is discussed.

Composting is a major part of Agaricus mushroom growing and the FSMA produce rule has specific requirements for the use of compost that contains materials of animal origin. Mushroom growers must recognize potential food safety hazards in their composting operations. This article summarizes the requirements and discusses research done at Penn State that will help growers comply with the rule.


Growers are increasingly supplementing traditional light peat in mushroom casing formulations with deep-dug dark peat. The impact this may have on the microbial ecology of casing soil has not been studied. We therefore expanded upon our earlier work to determine if dark peat supplementation might affect the survival of human pathogens in casing soils. We also determined the potential for pathogens to transfer from casing soil to mushrooms as well as the effects of irrigation treatments on pathogen survival.

Sphagnum peat-based casing soils do not permit the survival of *Listeria monocytogenes* and *Salmonella* sp. Chikthimmah, N., R. B. Beelman, L. F. LaBorde. 2006. Mushroom News. 54(9): 6-13

In the mushroom growing process, sphagnum peat amended with calcium carbonate added on top of mushroom mycelia-colonized substrate (compost) is called casing soil. The objective of the present study was to determine the survival of the foodborne pathogens *Listeria monocytogenes* and *Salmonella* sp. inoculated into sphagnum casing soils. Results demonstrated that commercial sphagnum-peat casing soils (that are not subjected to pasteurization or heat treatments) are effective in destroying introduced foodborne pathogens. The results also suggest that the native sphagnum-peat casing microflora are beneficial for food safety. Cultural practices such as thermal pasteurization may negatively affect the native casing microflora and hence compromise food safety. Therefore, thermal pasteurization of sphagnum-casing soils is not recommended.

**Avian Influenza Virus (AIV) Should the Mushroom Industry Be Concerned?** LaBorde, L. F. 2006. Penn State Extension Fact Sheet.

Avian influenza virus (AIV) is a group of viruses that can cause disease in birds and possibly humans. In this article, it is strongly suggested that the virus cannot survive the high temperatures achieved during composting of substrate containing poultry manure.


Some growers have heard from auditors that mushrooms should not be irrigated with water that contains nitrate levels that exceed the EPA limit of 10 mg NO3-N/L for potable water. This article summarizes a Penn state study that shows that mushrooms do not contribute significantly to dietary intake of nitrates, even when irrigated with high nitrate water.

**What is a Disinfectant or Sanitizer?** Beyer, D. M. Penn State Extension Fact Sheet.

Since mushroom growers often refer to disinfectants and sanitizers interchangeably, this discussion helps to clarify some terms.

**For Packers and Slicers**


Now is the time for the mushroom industry to take all possible measures to minimize risks for *Listeria* contamination. An understanding of the unique characteristics of *L. monocytogenes* is an essential first step toward taking actions to keep it out, keep it from growing, and kill it before it gets onto mushrooms.


Provides specific recommendations for reducing the occurrence of *Listeria monocytogenes* in mushroom pre- and post-harvesting environments.

**Sanitary and Design Considerations for Mushroom Packing and Slicing Operations Webinar**

In this recording of a Penn State Extension webinar, examples of mushroom facility and equipment sanitary design flaws are discussed along with strategies for reducing contamination risks.
**Listeria Guidance**

Government agency and commodity group guidance on minimizing Listeria and environmental testing.


United Fresh Produce Association (UFPA). 2nd ed. 2018. Guidance on environmental monitoring and control of Listeria for the fresh produce industry.

**Peer Reviewed Scientific Journal Articles**

Contact Luke LaBorde at lfl5@psu.edu if you were not able to access the full text of any of these articles.


**Abstract:** Industrial food slicing equipment that is difficult to clean and sanitize can become a reservoir of *Listeria monocytogenes*. Some commercial mushroom slicing operations have attempted to manage cross-contamination risks by periodically immersing detachable slicer heads in heated water maintained at varying temperatures for different times. In this study, the efficacy of hot water disinfection treatments to eliminate *L. monocytogenes* from commercial mushroom slicers was examined. Fourteen *L. monocytogenes* strains, including several obtained from mushrooms or mushroom processing environments, were screened for heat tolerance at 60 °C for 6 min. The 6 most heat tolerant strains were used to prepare a microbial cocktail for thermal inactivation studies. Heat tolerance of planktonic cells was not affected by incubation at 30 °C for up to 7 days, or the extent to which they adhered to stainless-steel coupons under the same conditions. Respective *L. monocytogenes* D50, D60, and D70-values of 11.5 min, 1.90 min, and 1.0 min were not higher than D-values for a *L. innocua* isolate at the same temperatures. Heat penetration studies, conducted on the slicer head immersed in a heated clean-out-of-place (COP) wash tank, determined that the slowest-to-heat food contact location (cold spot) was at the interface of one of the blade-spacers with the horizontal slicer drive shaft. A microbial challenge study was conducted by disassembling the slicer head, inoculating the cold spot with 7 log cells *L. innocua* surrogate, and subjecting the reassembled slicer head to water temperatures of 55 °C, 65 °C, or 75 °C for 93, 16.4, or 6.5 min. Complete elimination of *L. innocua* cells for each slicer head treatment demonstrated the feasibility of hot water sanitization treatments to minimize *L. monocytogenes* food safety risks.


**Abstract:** *Listeria monocytogenes* is a foodborne pathogen of significant concern to the agricultural and food processing industry because of its ability to grow and persist in cool and moist environments and its association with listeriosis, a disease with a very high mortality rate. Although there have been no listeriosis outbreaks attributed to fresh mushrooms in the United States, retail surveys and recalls are evidence that *L. monocytogenes* contamination of mushrooms (*Agaricus bisporus*) can occur. The objective of this study was to determine the prevalence of *Listeria* spp., including *L. monocytogenes*, in a small-scale mushroom production facility on the campus of the Pennsylvania State University in the United States. Of 184 samples taken from five production zones within the facility, 29 (15.8%) samples were positive for *Listeria* spp. Among the *Listeria* spp. isolates, *L. innocua* was most prevalent (10.3%) followed by *L. welshimeri* (3.3%), *L. monocytogenes* (1.6%), and *L. grayi* (0.5%). *L. monocytogenes* was recovered only from the phase I raw material composting area.


**Abstract:** Commercial production of white button mushrooms (*Agaricus bisporus*) requires a specialized growth substrate prepared from composted agricultural by-products. Because horse and poultry manures are widely used in substrate formulations, there is a need to determine the extent to which the composting process can eliminate human pathogens. Experiments conducted in the laboratory and in a phase II pilot facility on the Penn State campus showed that complete reduction of *Listeria monocytogenes*, *Escherichia coli* O157:H7, and *Salmonella* will occur during a standard 6-day mushroom industry Phase II process. Therefore, phase II composting process can be an effective control measure for eliminating risks associated with the use of composted animal manures during mushroom production. Growers are encouraged to validate and verify their own composting processes through periodic microbial testing for pathogens and to conduct studies to assure uniform distribution of substrate monitoring temperatures during phase II.

Predominance and Distribution of a Persistent *Listeria monocytogenes* Clone in a Commercial Fresh Mushroom Processing Environment
Abstract: A longitudinal study was conducted to determine the prevalence of *Listeria* spp. in a commercial fresh mushroom slicing and packaging environment. The VT11 virulence type was the overall predominant and persistent clone indicating that it likely colonized the mushroom processing environment. Areas adjacent to the trench drain in the washing and slicing area and a floor crack in the packaging area may represent primary harborage sites (reservoirs) for VT11. Improvements made to sanitation procedures by company management after period 2 coincided with a significant (P ≤ 0.001) reduction in the prevalence of *L. monocytogenes* from 17.8% in period 1 and 30.7% in period 2 to 8.5% in period 3. This suggests that targeted cleaning and sanitizing procedures can be effective in minimizing the occurrence of *L. monocytogenes* contamination in processing facilities. Additional research is needed to understand why VT11 was predominant and persistent in the mushroom processing environment.

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