Food Research Institute
UNIVERSITY OF WISCONSIN–MADISON

FRESH Seminar: "Molds, Mycotoxins, and Concerns of the Food Industry"

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MADISON, Wis. (FRI) – Fungi and their toxins can cause significant problems for the food industry. UW–Madison professor and FRI Executive Committee member Jae-Hyuk Yu, PhD, recently provided an overview of molds, mycotoxins, and associated industry concerns at the last FRESH seminar for the spring 2015 semester.

Fungi and animals belong to the "opisthokonts," a broad group of eukaryotes. Fungi exhibit extraordinary diversity and are predicted to have more than 5 million species. Of the five main phyla of fungi, two are of particular importance to the food industry: the Zygomycota (often a common concern in food) and the Ascomycota (sac fungi responsible for mycotoxins). Yeasts are unicellular fungi, while molds are multicellular.

Like plants, fungi have a cell wall; however, in fungi, the cell wall is made of chitin, while in plants, it is composed of cellulose. Fungi are non-photosynthetic, heterotrophic organisms, obtaining their carbon and energy from organic sources in their environment through their web-like hyphae. The molds can secrete enzymes from the tips of the hyphae to digest potential food sources; the digestion products can then diffuse back into the hyphae. Molds can grow rapidly, reproducing sexually or asexually via spores, which are typically more sensitive to environmental insults like heat than are bacterial spores.

Fungal food spoilage can be very obvious. Yeast can produce bubbles or foam, and mold growth may be evident as fuzzy growth in bright colors with a circular growth pattern. Fungal spoilage can lead to off-odors, discolorations, texture changes, heat, gas, and other notable effects. Food suspected of fungal spoilage should not be eaten.

Molds can grow in many types of food environments. An estimated 70% of all plant diseases are caused by fungi. Their ubiquity in plants and the ability of molds to tolerate acidic and dry conditions make them especially problematic to food producers. *Aspergillus* and *Penicillium* molds are common storage fungi that can survive at low water activities. Along with *Fusarium*, they represent important mycotoxin-producing food spoilage molds. *Aspergillus*, *Penicillium*, and *Rhizopus* are unusual in that they can grow on cured meats. Fungi of particular concern for dairy products include *Penicillium*, *Cladosporium*, and *Candida*, while *Botrytis, Rhizopus, Penicillium, Aspergillus,* and *Alternaria* are problematic on fresh fruits and vegetables. *Phoma descructiva* causes phoma rot on tomatoes and potatoes, resulting in black, leathery surfaces and circular depressed spots on the fruit.

Mycotoxins are toxic secondary metabolites produced by some fungi. More than 300 different mycotoxins are produced by about 150 various fungi, with most filamentous fungi making at least one or two mycotoxins. The toxic effects of mycotoxins can vary considerably. Unfortunately, mycotoxins are not readily destroyed by cooking, and their toxicities are not often treatable. Ingestion may trigger acute effects similar to the flu (headache, fever, nausea). In some cases, liver necrosis or death may swiftly occur. Chronic effects of mycotoxins include cancer and genetic or birth defects. Aflatoxin, itself a fairly inert compound, can be transformed by the liver, which then can cause mutations in the tumor suppressor p53. The loss of cell-cycle control that results makes aflatoxin one of the most potent carcinogens known. Ochratoxin is associated with kidney damage, while zearalenone has estrogen-like activities. Patulin, which is associated with apples, destroys the intestinal barrier.

Overall, 25% of the world's food crops are affected annually by mycotoxins. The annual losses in the U.S. and Canada due to mycotoxin's impact on feed and livestock is estimated at $5 billion. Mycotoxins are also huge problems in developing parts of the world, such as Africa. More than 100 countries have regulations regarding the levels of mycotoxins permitted in food and feed. Even with such control, contamination of food can occur, with tragic results, such as the 2004 aflatoxicosis outbreak in Kenya, which resulted in 125 deaths. The source of the outbreak was corn contaminated with high levels of aflatoxin B1, present at 220 times the regulatory limit for food in Kenya. The FDA has "action levels" for aflatoxins in various human or animal feed ranging from 0.5 ppb to 300 ppb, and patulin at 50 ppb, while other key mycotoxins have U.S. regulatory "advisory levels." The EU specifies strict and detailed limits for many different mycotoxins in the Commission Regulation 1881/2006.

Dr. Yu addressed several questions related to fungi problems in food production asked by audience members and FRI sponsor representatives.

1. **Are food spoilage fungi "true" pathogens?**

No, but there are many types of molds. Some types of fungus not associated with food can cause disease. For example, coccidioidomycosis is caused by *Coccidioides*, which is not found in Wisconsin. The mold *Blastomyces dermatitidis*, which is responsible for blastomycosis, is a problem in Wisconsin. Some food spoilage molds cause adverse effects through their production of allergens. The molds themselves do not generally cause systemic infections in humans, however, except in the immunocompromised.

2. **What happened in the yogurt/*Mucor* incident?**

In 2013, more than 400 consumers (not all are confirmed-cases) became ill after eating yogurt. The FDA reported that yogurt products were found to be contaminated with the fungal pathogen *Mucor circinelloides*, and the manufacturer issued a recall. A research group obtained a yogurt container from one of the consumers sickened in the outbreak and was able to isolate a *Mucor* strain from the container. The strain, which they dubbed "Mucho," appeared virulent, killing immunocompromised mice when 10^6 spores of the mold were injected into a mouse tail vein. However, mice with a healthy immune system did not succumb to Mucho. Mice that were orally administered the mold were still shedding Mucho in their feces 10 days later, demonstrating the organism could survive transit through the gastrointestinal tract. However, the mold had no effect on the length of the large intestine, which is a surrogate measure for intestinal inflammation.

No epidemiological evidence or statistical data conclusively demonstrated that Mucho was the causative agent for the illness. The mouse virulence data are not necessarily reflective of the human illness observed, especially given the high doses used and the intravenous route of administration. The human illness could have resulted from other complex changes in the yogurt, secondary metabolites, or altered fermentation. Ideally, the FDA, the company, and the research group will work together to continue investigating the outbreak.

3. **Why, where, and how does mold get into food and beverages?**

Mold is everywhere. Mold can grow at much lower water activities than other spoilage organisms, down to 0.75. Some fungi can survive more than 30 minutes at 75°C, so they can survive pasteurization. Asexual spores (conidia) are generally more susceptible to heat (and are produced in greater numbers) than are sexual spores (ascospores). Ascospores need to be activated in order to germinate, and heating, paradoxically, is one way to activate them.

Mold may be present in foods where not expected. At least 25 types of fungus were found in one common type of preservative-free juice packets. The acidity of the juice did not deter the fungus, and there was sufficient water activity, and potentially enough oxygen present in the package to support mold growth.

The best approach to prevent fungal spoilage of food is to try to stop entry of fungi if possible. Understanding how molds interact with the environment can also be useful in controlling mold-associated problems. For example, during periods of drought, plants are much more susceptible to molds, leading to more potential aflatoxin problems. However, other strategies may be effective if fungi are present. Organic acids, chelating agents, and gaseous compounds, such as chlorine dioxide, biocontrol agents using competing or other microbes, modified atmosphere packaging, fungicides, and certain naturally occurring compounds, are all strategies that have been used with some success against fungi.

About the Food Research Institute

The Food Research Institute (FRI), a part of the College of Agricultural and Life Sciences at the University of Wisconsin–Madison, operates its own laboratories and administers its own research and service programs. The mission of FRI is to catalyze multidisciplinary and collaborative research on microbial foodborne pathogens and toxins and to provide training, outreach and service to enhance the safety of the food supply. To fulfill this mission, FRI conducts fundamental and applied research, provides accurate and useful information and expertise, delivers quality education and training, and provides leadership in identifying and resolving food safety issues to meet community, government, and industry needs.

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