

Understanding the Potential Risks of Consuming Raw Morel Mushrooms: Challenges and Lessons Learned from a Recent Outbreak Linked to Raw Morel Mushrooms

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ABSTRACT

Foodborne poisoning from mushroom consumption remains a critical food safety concern. An outbreak of mushroom poisoning in Montana in 2023 was linked to morel mushrooms imported from China. After eating at a restaurant in Montana, 51 people experienced gastrointestinal illness, resulting in three hospitalizations and two deaths. Ultimately, the outbreak was linked to the consumption of undercooked and raw morel mushrooms, highlighting the importance of proper cooking to reduce toxin levels and mitigate the risk of illness. Concerns regarding potential harmful effects of consuming raw morels suggest the need for increased awareness and caution among consumers and restaurants. Relevant food safety recommendations since the outbreak occurred have become publicly available, including messaging to avoid the consumption of raw morels and thorough cooking of these mushrooms. The investigation revealed industry knowledge gaps in the safe preparation of morel mushrooms, shedding light on the impact of inadequate food safety measures. Regulatory guidance, voluntary labeling information, and further outreach to consumers promoting awareness and use of publicly available cooking advice may enhance awareness and safety regarding consumption of morel mushrooms.

INTRODUCTION

Mushrooms are the fruiting bodies of certain species of fungi, and many types of mushrooms can be toxic if eaten (37). Distinguishing between edible and poisonous species can be difficult, even for experienced foragers, and some edible species, including some that are commercially cultivated, can be toxic to some consumers (37).

Foodborne intoxication from mushroom consumption is a well-documented phenomenon, both domestically and glob-

ally and can manifest in various ways (26). One of the most common clinical outcomes is acute gastroenteritis, resulting in nausea, vomiting, abdominal cramping, and in some cases diarrhea within 1 to 3 h. Other clinical signs include headache, vertigo, somnolence, palpitations, dysrhythmia, rhabdomyolysis, methemoglobinemia, hemolysis, erythromelalgia, and dermatitis. Mushroom poisoning can be mistaken for other acute illnesses, making it difficult to definitively implicate the causative vehicle and hazard.

The annual global fatality rate from eating poisonous species of mushrooms is unknown but has been estimated to be at least 100 deaths per year (3, 6). Mushroom intoxication was the leading reported cause of foodborne illness outbreaks and outbreak-associated deaths in the People's Republic of China from 2010 to 2020, and outbreaks have been described in Israel, Iran, France, Spain, Germany, Canada, Thailand, and other countries (15–17, 24, 25). In the United States, approximately 7,500 incidents of mushroom intoxication are reported annually (2). Many mushroom intoxication cases are due to accidental consumption or misidentification of poisonous mushroom species. However, some species of edible mushrooms have a potential for toxicity when handled or prepared incorrectly.

Morel mushrooms are edible, and some people consider them choice. They are commonly foraged from the wild but also can be cultivated for commercial sale (36). True morels in the genus *Morchella* have been implicated in foodborne illness outbreaks in several countries. Affected individuals have reported gastrointestinal symptoms and neurologic symptoms, particularly when the mushrooms were consumed raw or undercooked (23). Previous outbreaks described in the literature include four ill people in Spain in 1991 (22); six in Germany in 2008; 30 in Valencia, Spain in 2019; and 77 in Vancouver, Canada in 1992 (4, 21–23). Illnesses due

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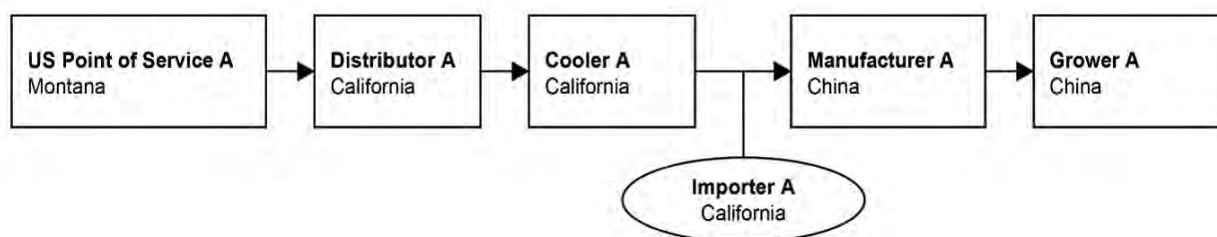


FIGURE 1. Traceback diagram for and outbreak of foodborne illness associated with consumption of morel mushrooms sourced from China. The source of the illness in people dining at restaurant A in Montana was traced back from exposure through the distribution chain to a foreign manufacturer.

to consumption of morels have been described frequently enough that recent work conducted to create a taxonomy of mushroom poisoning assigned morel neurologic syndrome to its own category (37). This neurologic syndrome has been characterized by cerebellar signs (including tremor, dizziness, or inebriation) or unsteadiness and ataxia associated with gastrointestinal symptoms (14). Morel neurologic syndrome is typically associated with consumption of large quantities (up to 600 g) of raw or poorly cooked morels (14).

In April 2023, federal, state, and local regulatory partners investigated an illness outbreak in Montana linked to the consumption of cultivated morel mushrooms sourced from the People's Republic of China. Preliminary findings from this investigation have been previously reported elsewhere (5). Here we report on the outbreak investigation focusing on the laboratory and traceback investigations, as well as the lessons learned and associated guidance available for consumers and industry. This outbreak revealed knowledge gaps regarding safe preparation of morel mushrooms prior to consumption.

MATERIALS AND METHODS

Epidemiology. On 18 April 2023, the Montana Department of Public Health and Human Services (MT DPHHS) and local health departments in Montana were notified of two individuals who developed severe nausea, vomiting, and diarrhea within 60 min of their meal after independently eating at the same restaurant on 17 April. On 21 April 2023, the U.S. Food and Drug Administration (FDA) was notified of five adverse events, potentially linked to consumption of morel mushrooms used as an ingredient in sushi rolls served at restaurant A, a sushi restaurant in Montana. MT DPHHS investigated to identify the extent and source of the outbreak, as previously described (5). The investigation revealed that 51 people developed gastrointestinal illness after eating at this restaurant, of whom 3 were hospitalized and 2 died. Consumption of morel mushrooms was strongly associated with these illnesses, and the association was stronger for the consumption of raw

morel mushrooms than for mushrooms that were at least partially cooked (5).

Symptoms. Illnesses in this outbreak included diarrhea, nausea, abdominal pain, loss of appetite, fatigue, and vomiting. The four ill people who were hospitalized or sought emergency medical care had a rapid onset of gastrointestinal symptoms, including profuse vomiting, diarrhea, and dehydration (5).

Investigational activities. On 18 April 2023, the Gallatin City-County Health Department (GCCHD) in Montana conducted an inspection at restaurant A after receiving reports of two individuals who had experienced severe nausea, vomiting, and diarrhea after independently eating at the same restaurant in Montana on 17 April. One person was hospitalized, and the second person died hours after being discharged from the hospital emergency department. As a result, the restaurant was ordered to close on 20 April 2023 (8).

Traceback. The FDA, in collaboration with state and local health departments, conducted a traceback investigation of morel mushrooms at restaurant A to document the movement of mushrooms through the supply chain and points of distribution, processing, and production (13). The single traceback leg identified a single distributor, cooler, importer, manufacturer, and grower (Fig. 1). Three import entries of morel mushrooms from grower A were delivered to restaurant A during the timeframe of interest. Records collected from distributor A and importer A revealed that restaurants in other states received morel mushrooms from the same supplier during the same timeframe as did restaurant A in Montana. The FDA collaborated with the California Department of Public Health (CDPH) to gather retail point-of-service information related to receipt, handling, and cooking practices for morel mushrooms at the restaurants that received the same morel mushrooms as did restaurant A. This effort was initiated to try to explain why there were only localized cases at restaurant A. The CDPH collected information from six California restaurants to determine their product receiving and handling practices.

All six restaurants noted that they cooked morel mushrooms before serving and did not receive any complaints of illness from patrons or staff.

Laboratory testing. The MT DPHHS and GCCHD coordinated with the FDA and the Centers for Disease Control and Prevention (CDC) toxicology and enteric disease groups for food specimen testing. The FDA conducted laboratory analyses of samples collected by the GCCHD from restaurant A. Samples were collected 1 day after the majority of illnesses occurred and comprised small amounts of leftover meal remnants, including morel mushrooms and salmon. Each sample was split into three subsamples. The CDC also conducted microbiological analysis of the same morel mushroom and salmon samples. The FDA laboratories completed microbiological analysis, DNA testing, and screening for heavy metals (10), pesticides, toxins, and poisons. The FDA samples were analyzed according to their Office of Regulatory Affairs laboratory manual (35) and the *Bacteriological Analytical Manual* (32).

The food samples were negative for staphylococcal enterotoxin and *Bacillus cereus* diarrheal enterotoxin and emetic toxin. DNA sequencing of a morel mushroom sample identified it as a “true” morel mushroom, *Morchella sextelata*. Heavy metal testing (10) revealed that the morel mushroom samples were within compliance levels, and arsenic, cadmium, lead, and mercury were all under the reference levels. Two stool specimens collected from ill persons on 20 April 2023 were negative for *Clostridium perfringens* enterotoxin. No cereulide, hydrazine, or other drugs or poisons were identified in the analyzed portions of morel mushrooms by liquid chromatography–mass spectrometry.

Communications. The MT DPHHS and GCCHD issued a joint web post on 3 May 2023 (20), the GCCHD issued an additional web post on 17 May 2023 (8), and the FDA issued a public health advisory press release regarding the outbreak on 19 May 2023 (36). The MT DPHHS and GCCHD issued a final summary of the outbreak on 19 July 2023 (19).

RESULTS AND DISCUSSION

Preparation and consumption of morel mushrooms

Guidance regarding the necessity of cooking certain mushrooms does appear in scientific literature. A well-known clinical toxicology reference, *Goldfrank's Toxicologic Emergencies* (9), advises that no mushrooms should be eaten raw and names the honey mushroom, thimble-cap (or early morel) mushroom, and true morels in particular as those that require cooking before consumption: “even the *Morchella esculenta*, the edible-choice morel, is well recognized to cause dizziness, tremor, and ataxia when eaten raw in large quantities.”

Assessment of consumer knowledge and consumption of specialty foods can be difficult or cost-prohibitive. However, examination of how a food is discussed in popular media or suggested for use in recipes may provide some indication

of how a particular food item may be prepared and eaten. Although the prevalence of eating raw morels is unknown, at least one recipe published online omits any heating steps (7). Many sources of guidance about the harvest and preparation of morels caution against consuming raw mushrooms but with various degrees of emphasis. Comments range from “[if morels] are undercooked or eaten raw or eaten with alcoholic beverages, one may become ill [emphasis in original]” (18) to “Morels are better off cooked than consumed raw. Eating raw morels can lead to some stomach pain for those with sensitive stomachs” (11).

The toxins in morel mushrooms that may cause illness are not fully understood, but a growing body of evidence suggests that morel mushrooms can be toxic when eaten raw. Consumer recipes, anecdotal information collected from restaurants, and recent epidemiologic evidence indicate that cooking can help reduce toxin levels (36). In the large outbreak in Canada in 1992, guests were served raw morels (23). In the 2023 outbreak in Montana, ill people had ingested uncooked or undercooked morel mushrooms.

Outbreak hypotheses

The combination of the epidemiologic and traceback investigations and the extensive laboratory testing of food samples helped investigators narrow down the most likely cause of illness to ingestion of uncooked or undercooked morel mushrooms. The exact cause of the outbreak remains unknown; however, two possible scenarios were considered.

The inspection at restaurant A that occurred after the outbreak revealed that morel mushrooms were a new item on the menu and had not been served before March 2023. Morel mushrooms offered by restaurant A were served either undercooked or raw. Restaurants in other states received morel mushrooms from the same supplier during the same timeframe as did restaurant A. All six of the restaurants that responded to inquiry reported some type of heating method, including cooking, sautéing, or otherwise thoroughly heating the mushrooms before serving, and none of them reported receiving any consumer complaints after eating morels. Restaurant A staff mentioned that they were unaware that cooking was necessary before serving morel mushrooms. Properly preparing and cooking morel mushrooms can reduce the risk of illness; however, cooking provides no guarantee that the mushroom consumer will not become ill (36).

Consumption of raw or undercooked morel mushrooms can lead to gastrointestinal symptoms such as nausea, vomiting, diarrhea, and abdominal pain and neurological symptoms such as dizziness, balance problems, and disorientation (36). Most individuals in this investigation who became ill after dining at restaurant A reported gastrointestinal symptoms. Generally, symptoms of mushroom poisoning depend on the type of mushroom consumed, the specific toxin present, and the amount

ingested and can differ among consumers, some of which may be more susceptible than others (36). These observations support the conclusion that the lack of thorough cooking of the morel mushrooms was the determining factor that caused illness among patrons and restaurant employees.

An alternative hypothesis is that the morel mushrooms contained something other than their natural toxins that caused clinical signs similar to those of morel toxicity. The morel mushroom analysis results were inconclusive for identifying the cause of the outbreak and the associated deaths and hospitalizations. These analyses ruled out contamination with multiple external chemicals and microbiological toxins that were within the testing capabilities of the FDA lab. It was not possible to test directly for the presence of the toxic components of morel mushrooms. Nonetheless, there are several possible explanations for these results and the cause of the outbreak. Variability in the test results of the morel mushroom samples suggests that the samples analyzed may not have been representative of products ingested by the ill persons. Because the small samples tested were collected 1 day after the illnesses occurred and the mushrooms had been harvested over an unknown time period, these samples may not have included the causative agent, if there was one. Investigators were hopeful that laboratory results would shed light on the etiology of the illness and therefore its source. Although the etiology of this outbreak could not be defined via laboratory testing, investigators determined based on the epidemiologic evidence and the high odds ratio reported previously (5) that morel mushrooms were the most likely cause of illness.

Although the mushrooms collected from restaurant A for analysis were true morels, varieties of false morel mushrooms in the genus *Gyromitra* are similar in appearance and can be mistaken for a true morel. Although false morels are prepared and eaten in some cultures, they are generally regarded as inedible, and consumption should be avoided. *Gyromitrin* is a toxin found in some varieties of false morels that has been linked to several cases of mushroom poisoning and can be fatal in even relatively small amounts (12). *Gyromitrin* poisoning can cause symptoms such as headache, vomiting, diarrhea, dizziness, loss of coordination, and in severe cases seizures, heart failure, liver and kidney damage, and death. *Gyromitrin* toxin can be partially broken down by high temperature; however, the toxin may remain after cooking and can lead to illness or poisoning (36). At the start of the Montana outbreak, investigators thought that the product served could have been a false morel, but this hypothesis was quickly ruled out after the mushrooms were positively identified as morels. Given the vast clinical landscape of mushroom toxicity, the various manifestations of illness must be understood to accurately diagnose and treat mushroom poisoning.

Morel mushroom food safety practices and recommendations

Mushrooms are a covered commodity under 21 CFR 112, known as the Produce Safety Rule (PSR) (27). A farm (either a primary production farm or secondary activities farm, defined in 21 CFR 1.227 (28)) can be an operation that is devoted to only the harvesting of covered produce from the wild. Therefore, wild-foraged mushrooms are not exempt from the requirements of the PSR. The harvesting activity and any other covered activities regarding covered produce that are conducted by the farm must comply with applicable requirements in the PSR. The PSR standards are intended to limit microbial contamination that may occur during growing, harvesting, packing, and holding activities. However, the PSR does not establish standards for ensuring that commercially cultivated or wild-harvested mushrooms are free of naturally occurring toxins that may lead to poisoning of consumers. The food labeling regulations set forth in 21 CFR 101 (29) do not require producers of mushrooms (commercially cultivated or wild harvested) that contain naturally occurring toxins to disclose this on the label. They also do not require mushroom producers to include information on safe handling and preparation of the mushrooms. However, the FDA does not object to the voluntary inclusion of label information regarding the presence of the toxins or safe handling instructions provided this information is truthful and not misleading. Importers of mushrooms must comply with the rule on foreign supplier verification programs (31, 33). This rule requires importers to perform risk-based foreign supplier verification that (i) the mushrooms are produced in a manner that provides the same level of public health protection as does the PSR; (ii) the mushrooms are not adulterated as per section 402 of the Food, Drug, and Cosmetic Act (21 U.S.C. 342) (30); and (iii) the mushrooms are not misbranded as per section 403(w) of this act with regards to food allergen labeling requirements (31, 33).

The FDA Food Code (34) establishes model regulatory requirements for adoption by state, local, tribal, and territorial regulatory programs that regulate retail food establishments. The Food Code recommends that mushroom species picked in the wild shall not be offered for sale or service by a food establishment unless the food establishment has been approved to do so by the regulatory authority that issued the permit to operate. The Food Code also recommends that the person in charge shall be knowledgeable about foodborne disease prevention, hazard analysis and critical control point principles (including critical control points in the operation from purchase through sale or service), and the control of risk factors that impact the safety of the food they sell or serve. However, the Food Code does not establish a model regulatory requirement for a minimum cooking temperature for mushrooms (or other raw agricultural commodities) that might otherwise require

cooking to reduce naturally occurring toxins. In 2021, the Association of Food and Drug Officials (1) developed a guidance document to provide the regulatory authority with models for approval of food establishments and harvesters in their jurisdiction. This document included some of the more common wild-harvested mushrooms of culinary value that are generally not easily confused with more toxic species (9). This guidance document also suggested that mushrooms such as morels should be handled and prepared safely, emphasized the importance of thorough cooking, and recommended that beginner harvesters avoid collecting mushrooms with gills and monitor collected mushrooms for signs of spoilage or contamination.

CONCLUSIONS

Raw or undercooked morel mushrooms can cause severe poisoning to consumers. Morel mushrooms were identified as the vehicle for the illness outbreak in Montana based on epidemiologic and traceback evidence that showed clear association between consumption of morel mushrooms and gastrointestinal illness. Of the 51 individuals who reported mild to severe gastrointestinal illness after eating at restaurant A in Montana, 3 were hospitalized and 2 died. The specific toxin or pathogen contamination in the morel mushrooms served at the restaurant is unknown and could not be

confirmed through laboratory testing. However, investigators hypothesized that inadequate cooking of morel mushrooms led to foodborne poisoning of the patrons. This outbreak highlights need for increased awareness and emphasis on the potential dangers of consuming morels in their raw or undercooked state. Public health officials should consider whether the current regulatory framework of farm to fork is adequate to enable the safe consumption of commercially cultivated mushrooms that have naturally occurring toxins and require cooking before consumption.

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