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Toxic Mushroom Contamination of Wild Mushrooms in Commercial Distribution

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ABSTRACT

Poisonings caused by ingestion of toxic, wild-picked morel mushrooms have been reported to the Food and Drug Administration (FDA). Problems occur when collectors of wild mushrooms inadvertently include toxic look-alike species with the edible wild species offered for sale. A 2-year survey conducted by the FDA showed 21% of the morel and 15% of the wild mixed mushrooms were contaminated with toxic look-alike species. These contaminants contain toxins that produce symptoms ranging from dizziness and gastrointestinal distress to liver and heart damage. Present regulatory controls include FDA Import Alerts for morels contaminated with *Gyromitra esculenta* and *Verpa bohemica*, a Michigan state regulation requiring licensing of harvesters of wild mushrooms, and an Illinois state regulation prohibiting the sale of wild-picked mushrooms through retail outlets. American consumers, unable to distinguish between edible and toxic look-alike wild mushrooms, may face illness and possibly death from products purchased on the normally well-regulated U.S. consumer market.

The health implications of ingesting toxic mushrooms have been well-established; however, consumers of wild mushrooms in the U.S. marketplace continue to be exposed to toxic look-alike contaminants. The consequences of these potential poisonings range from unpleasant gastrointestinal disturbances to major organ failure and death. In a New York restaurant in 1977, four people became ill after consuming morels (*Morchella* sp.) Dill. ex Fr. contaminated with the toxic false morel *Gyromitra esculenta* (Pers. ex Fr.) Fr. (*20*). In 1980, the Food and Drug Administration (FDA) refused to allow importation of a shipment of morels because of contamination with *G. esculenta* (*20*). In 1987, a Detroit man was hospitalized with symptoms resembling amanita hepatotoxicity after consuming a morel sauce. Analysis of the mushrooms used to prepare the sauce showed contamination by *G. esculenta* and the early morel *Verpa bohemica* (Krombh.) Schroet (*21*). Between 1980 and 1987, 13 foreign shipments of morels were refused entry into the United States because of contamination by toxic look-alike species, namely *G. esculenta*, *V. bohemica*, and *Helvella* sp. L. ex Fr.

SOURCE AND PROCESSING PROBLEMS

Consumers are exposed to wild mushrooms from many sources. They can harvest wild mushrooms for their own personal use, buy mushrooms from businesses that collect and sell mushrooms to the public and retail distributors, or order dishes that contain wild mushrooms in restaurants. To meet the consumer demand, retail food stores and restaurants are offering an increasing variety of wild mushroom species and mushroom dishes, respectively. This increased market demand, along with potentially serious domestic and foreign supplier problems, greatly increases the threat of mushroom intoxications.

Wild mushrooms from commercial sources may be contaminated by toxic look-alikes, which are collected with edible mushrooms through either ignorance or negligence. Mushroom pickers are often paid by the pound for their wild harvest, a practice that discourages selective harvesting and culling for the elimination of undesirable species and that encourages fraud. Field drying the wild harvest before sale to cooperative processing and packaging operations makes effective culling more difficult because the appearance of the dried product is changed.

REGULATORY CONTROLS

Federal regulatory activities in the wild mushroom market presently include an Import Alert that provides all FDA District offices with specific information on the contamination of morels by *G. esculenta* and *V. bohemica*. The Import Alert directs the automatic detention of morels manufactured or shipped by specific firms because of their violative history (*20*). Under the alert, all of the morels offered for entry into the United States by the identified firms are detained, sampled, and analyzed for the presence of toxic contaminants. Products sampled under Import Alerts are normally analyzed by private analytical laboratories; however, because the availability of experts who can recognize and identify toxic mushrooms is limited, a team of trained experts in the agency's Division of Microanalytical Evaluations performs all the morel analyses. Morel shipments from other manufacturers are subject to routine import inspection surveillance at the port of entry.

Limited state and local laws exist to regulate the sale of wild mushrooms. For example, the State of Michigan licenses growers and harvesters of wild mushrooms, whereas Illinois prohibits the sale of wild-picked mushrooms through wholesale, retail, or food service establishments (*19*).

THE SURVEY: SAMPLE COLLECTION

Sample collection

Ten FDA Districts each were directed to collect 30 samples of canned and dried imported mushrooms for 1 year (beginning October 1988) and 20 samples of canned, dried, and fresh im-

ported and domestic mushrooms for 1 year (beginning October 1989) (*21*). For this survey, wild mushrooms are defined as those that were grown completely in their natural habitat or were cultivated, harvested, and processed under conditions not subjected to routine regulatory surveillance (*20*) (Table 1).

The mushrooms collected and analyzed during the 2-year survey are shown in Table 2. Of 375 samples received, 344 were analyzed. Thirty-one samples were not analyzed because they were either the wrong type, such as finely chopped or powdered, or were fresh samples that were too decomposed to identify.

RESULTS

Sample identification

Toxic species found in survey samples are shown in Table 3. *V. bohemica* or *G. esculenta* were found in 21.4% of the morels, with concentrations from 0.06 to 2.83% by weight. *V. bohemica* was found in 15.4% of the mixed mushroom samples, with concentrations from 0.0002 to 0.15% by weight. Mushroom samples collected and contaminants recovered from these samples were identified by trained analysts, using macroscopic and microscopic morphology keys and technical descriptions in the references cited in Table 2. Seven of the nine morel samples that contained toxic species were imported from France; the two remaining samples were from India. Both mixed mushroom samples that contained toxic species originated in France.

TABLE 1. *Mushrooms specified for collection by the Food and Drug Administration.*

Common name	Genus, species
Morels	*Morchella* sp.
False morels	*Gyromitra* sp. Fr.
Early morel, bell morel	*Verpa* sp. Swartz ex Fr.
Lorchels	*Helvella* sp. L. ex Fr.
Steinpilz, porcini, cepes	*Boletus* sp. Dill ex Fr.
Forest medley, mixed	Various
Wild mushrooms	Various
Enoki, golden mushroom	*Flammulina velutipes* (Curt. ex Fr.) Singer
Matsutake	*Armillaria ponderosa* (Pk.) Sacc.
Chanterelles, trumpet mushroom	*Cantharellus* sp. Adans. ex Fr. *Craterellus* sp. Pers.
Oyster, abalone, hiratake	*Pleurotus* sp. (Fr.) Quel.
Meadow mushroom	*Agaricus campestris* Fr.
Coral, gold spear	*Ramaria* sp. Holmskjold ex S.F. Gray *Clavaria* sp. Fr. *Clavariadelphus* sp. Donk *Clavicorona* sp. Doty
Shiitake	*Lentinus edodes* (Berkeley) Pegler
Straw mushroom	*Volvariella volvaceae* (Bull. ex Fr.) Singer

TABLE 2. *Distribution of mushrooms collected.*

Common names[a]	No. of samples	% of samples
Shiitake	70	20.3
Porcini, cepes, steinpilz	55	16.0
Chanterelles, trumpet mushroom	45	13.1
Morels	42	12.2
Oyster, abalone, hiratake	42	12.2
Straw mushroom	42	12.2
Enoki, golden mushroom	17	4.9
Mixed, forest medley	13	3.8
Brown ear fungus, jelly fungus	5	1.5
Agaricus sp.	3	0.9
Hedgehog mushroom	3	0.9
Pholiota nameko	3	0.9
Matsutake	2	0.6
Cauliflower mushroom	1	0.3
Caesar's mushroom	1	0.3

[a] References *1, 4, 11, 12, 15, 16,* and *23.*

TABLE 3. *Distribution of toxic mushrooms in survey samples.*

Mushrooms	No. of samples collected	Toxic species found[a]	No. of samples with toxic mushrooms	Percentage
Morel	42	*V. bohemica*	6	14.3
		V. bohemica and *G. esculenta*	3	7.1
Mixed	13	*V. bohemica*	2	15.4

[a] References *1, 23.*

TOXIC LOOK-ALIKE CONTAMINANTS

Table 4 lists the common edible wild mushrooms collected from commercial channels and their toxic look-alikes. The toxins from these mushrooms fall into three distinct groups: protoplasmic poisons, neurotoxins, and gastrointestinal irritants (*2,7,10,22*).

Toxic look-alikes in the protoplasmic poison group include several deadly amanitas: death angel (*Amanita bisporigera*) Atk., fool's mushroom (*A. verna*) (Bull. ex Fr.) Roques., destroying angel (*A. virosa*) (Fr.) Bertillon, and death cap (*A. phalloides*) (Fr.) Link (Table 4). These toxic look-alikes contain the cytotoxin amanitin, which causes gastrointestinal pain, violent vomiting, and diarrhea. After an apparent clinical improvement, more serious symptoms of liver, kidney, and intestinal damage occur, including jaundice, hypoglycemia, and kidney failure. After severe headaches, mental confusion, coma, and convulsions, death occurs in 50-90% of the cases (*2,6-10,13,14,22*).

The false morel (*G. esculenta*) and hooded false morel (*G. infula*) (Schaeff. ex Fr.) Quel. produce gyromitrin, a protoplasmic poison whose action is similar to amanitin, but less severe (Table 4). Gyromitrin is hydrolyzed by the body to monomethylhydrazine. The initial symptoms of gyromitrin ingestion are diarrhea, nausea, vomiting, headaches, dizziness, and loss of coordination. High fevers, convulsions, liver damage, or heart failure cause death in 2-4% of the cases (*3,5,7,17,18*). The early morel (*V. bohemica*), a frequent contaminant of edible morels, has also been implicated in poisonings. The symptoms it causes are similar to those caused by gyromitrin, but *V. bohemica* is generally a gastrointestinal irritant. The onset of symptoms caused by ingestion of *V. bohemica* depends on individual response thresholds to the toxin and on the quantity and frequency of consumption. The consumption of *V. bohemica* along with alcoholic beverages has also been reported to produce dizziness. The toxin is unidentified, but it is probably a hydrazine derivative similar to gyromitrin (*2,22*).

TABLE 4. *Edible wild mushrooms collected during the survey and some common toxic wild look-alike species.*

Edible commercial wild mushrooms	Common toxic wild look-alike mushrooms[a]	Toxins[b]	Predominant symptoms[c]	Prognosis[d]
Common morel *Morchella esculenta*) Fr. and other *Morchella* species	False morel (*Gyromitra esculenta*) and other *Gyromitra* species	Gyromitrin	Monomethylhydrazine poisoning: gastrointestinal symptoms, weakness, jaundice, loss of coordination, and sometimes coma and death	2-4% mortality
	Early false morel (*Verpa bohemica*)	Unidentified	Gastrointestinal symptoms and loss of coordination	No reported fatalities
Meadow mushroom (*Agaricus campestris*) and other *Agaricus* species	Death angel (*Amanita bisporigera*)	Amatoxin	Stage 1 - delayed gastro-intestinal symptoms	Poor - 50-90% mortality
	Fool's mushroom (*Amanita verna*)	Amatoxin	Stage 2 - apparent clinical improvement	
	Destroying angel (*Amanita virosa*)	Amatoxin	Stage 3 - liver and kidney failure, coma, and death	
	Death cap (*Amanita phalloides*)	Amatoxin		
	Fly agaric - white form (*Amanita muscaria*)	Ibotenic acid	Drowsiness, dizziness, hyperactivity, illusions, excitability, and delirium	Fatalities rare
Caesars mushroom (*Amanita caesarea*)	Death cap - yellow form (*Amanita phalloides*)	Amatoxin	Drowsiness, dizziness, hyperactivity, illusions, excitability, and delirium	Poor - 50-90% mortality
	Fly agaric - yellow form (*Amanita muscaria*)	Ibotenic acid	Drowsiness, dizziness, hyperactivity, illusions, excitability, and delirium	Fatalities rare
	Panther cap - yellow form (*Amanita pantherina*)	Ibotenic acid		
Honey mushroom (*Armillariella mellea*)	Autumn skullcap (*Galerina autumnalis*)	Amatoxin	Drowsiness, dizziness, hyperactivity, illusions, excitability, and delirium	Poor - 50-90% mortality
	Galerina marginata	Amatoxin		
	Fly agaric - yellow form (*Amanita muscaria*)	Ibotenic acid	Drowsiness, dizziness, hyperactivity, illusions, excitability, and delirium	Fatalities rare
	Panther cap - yellow form (*Amanita pantherina*)	Ibotenic acid		
	Showy flamecap (*Gymnopilus spectabilis*)	Psilocybin	Hallucinations	Fatalities rare, <1%
	Sulphur cap (*Naematoloma fasciculare*)	Unidentified	Gastrointestinal, and reports of amatoxin-like poisoning symptoms[e]	Fatalities reported
	Jack-o-lantern (*Omphalotus olearius*)	Unidentified	Gastrointestinal, and reports of muscarine poisoning symptoms[f]	No reported fatalities
Fairy ring mushroom (*Marmasmius oreades*)	Sweat mushroom (*Clitocybe dealbata*) and various *Inocybe* species	Muscarine	Profuse salivation, perspiration, and lacrimation. In severe cases gastrointestinal distress, blurred vision labored breathing, and rarely cardiac or respiratory failure	Fatalities rare
	Haymaker's panaeolus (*Panaeolus foenisecii*)	Psilocybin	Hallucinations, coma reported	Fatalities rare, <1%

TABLE 4. *Continued.*

Edible commercial wild mushrooms	Common toxic wild look-alike mushrooms[a]	Toxins[b]	Predominant symptoms[c]	Prognosis[d]
Coral fungi (*Clavicorona pyxidata*) and (*Ramaria apiculata*)	*Ramaria formosa* and *Ramaria gelatinosa*	Unidentified	Gastrointestinal (diarrhea)	No reported fatalities
Chanterelle (*Cantharellus cibarius*)	Jack o'lantern mushroom (*Omphalotus olearius*)	Unidentified	Gastrointestinal, and reports of muscarine poisoning symptoms	Fatalities rare

[a] See reference 22.
[b] See references *5-10* and *22*.
[c] See references *5, 7, 8, 10, 13,* and *22*.
[d] See references *2, 5, 7, 8,* and *13*.
[e] Defined in *Amanita* poisonings.
[f] Defined in sweat mushroom poisonings.

The neurotoxins found in wild mushrooms include ibotenic acid, psilocybin, and muscarine (Table 4). Ibotenic acid is found in the fly agaric [*A. muscaria* (L. per Fr.) Hook.] and the panther cap [*A. pantherina* (D.C. ex Fr.) Krombh]. Ibotenic acid is converted by the body to muscimol, which causes symptoms similar to alcohol inebriation. The compound can also cause gastrointestinal disturbances, seizures, dizziness, loss of coordination, and deep sleep with vivid dreams. After waking, victims may experience periods of elation, hyperactivity, and auditory and visual distortions. Reports of death from ingestion of mushrooms containing ibotenic acid are questionable and range from 0 to 5% (*2,6,10,22*).

Psilocybin is found in the showy flamecap [*Gymnopilus spectabilis*) (Fr.) A. H. Smith] and the haymaker's panaeolus [*Panaeolus foenisecii* (Fr.) Kuehner] (Table 4). The body converts psilocybin into the bioactive compound psilocin, which induces varying hallucinogenic states that end in sleep. Fatalities caused by psilocin are rare in adults but do occur among children (*2*).

Muscarine is found in the sweat mushroom [*Clitocybe dealbata* (Sow. ex Fr.) Kummer] and various *Inocybe* (Fr.) Fr. species (Table 4). Muscarine toxin affects the parasympathetic nervous system, causing profuse sweating, nausea, vomiting, excessive salivation, and nasal and eye discharge. Severe cases result in lowering of blood pressure and pulse rate, shock, and death due to respiratory or cardiac complications in about 5% of the cases (*2,6,7,10,22*).

Gastrointestinal irritants are produced by some prized edible mushrooms as well as wild look-alike species. Edible true morels, such as the narrow-capped morel (*Morchella angusticeps*) Peck, are gastrointestinal irritants for some people when consumed with alcoholic beverages, causing symptoms ranging from a hot flushed feeling in humans to palpitations, nausea, vomiting, and diarrhea (*5*) (Table 4).

Toxic look-alike mushrooms that produce gastrointestinal irritation include the sulphur cap [*Naematoloma fasciculare* (Huds. ex Fr.) Karst.] and the jack o'lantern mushroom [*Omphalotus olearius* (D.C. ex Fr.) Singer] (Table 4). These toxic look-alike mushrooms contain unidentified or poorly characterized compounds that cause nausea, vomiting, salivation, and diarrhea (*2,7*). The toxic coral fungi *Ramaria formosa* (Fr.) Quel. and *Ramaria gelatinosa* (Coker) Corner cause diarrhea (*7*).

CONCLUSIONS

All of the survey samples of wild mushrooms that were contaminated with toxic look-alike species were imported.

Many toxic species can be mistaken for edible varieties. Today in the United States, wild mushrooms available for retail sale are harvested by trained, experienced entrepreneurs and less knowledgeable amateurs. American consumers face possible illness or even death from the consumption of toxic wild mushrooms purchased on the normally well-regulated U.S. consumer market.

Note: The abbreviations for the names of authors of genera and species are used in accordance with references (*1*) and (*12*).

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Editors Note:
The article 'Modeling the Effect of Temperature on the Growth Rate and Lag Time of *Listeria inoccua* and *Listeria monocytogenes*', by Yeu-Hsin Duh and Donald W. Schaffner, published in the March 1993 issue of the Journal of Food Protection, pages 205-210, was found to have the following corrections by the author after publication.

Errata to Vol. 56, No. 3, March 1993
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Correction 1:

The paragraphs preceding and following equation 17 should be deleted.

In their place it should read:

Where

2.303 (slope) = μ [17]

Correction 2:

The paragraph following Equation [12] and preceding equation [13] should be deleted.

In its place it should read:

Hyperbolic Model. **Zwietering et al. (*13*) proposed that a hyperbolic equation would describe the relationship between lag time and incubation temperature based on the results of Gill et al. (*4*) and Adair et al. (*1*).**