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"GLOWING" SEAFOOD?

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Introduction

Seafood that produces a bright, blue-green light in the dark could be a meal from outer space or haute cuisine in a science fiction novel. The U. S. Food and Drug Administration (FDA) has received many consumer complaints about various seafood products "glowing" in the dark. Some of these consumers called their local health departments, poison control centers, and their U.S. Senator because they thought they had been poisoned by radiation. These consumers said they had trouble convincing people that their seafood was emitting light. One consumer took his imitation crabmeat to a local television station. Unfortunately his seafood had dried out and did not glow for the television reporters. Several consumers said that it took them many weeks before they found phone numbers for various government agencies to make inquiries.

Several consumers thought their "glowing" seafood was due to phosphorescing phytoplankton, or even fluorescence. The consumers' seafood products "glowing" in the dark were not due to radiation or to fluorescence, which requires an ultraviolet light to trigger the reaction. These seafood products exhibited luminescence due to the presence of certain bacteria that are capable of emitting light. Luminescence by bacteria is due to a chemical reaction catalyzed by luciferase, a protein similar to that found in fireflies. The reaction involves oxidation of a reduced flavin mononucleotide and a long chain aliphatic aldehyde by molecular oxygen to produce oxidized flavin plus fatty acid and light (5, 12). The amount of light emitted by cultured luminescent bacteria depends on the composition of the media used for culturing, incubation temperature, age of the culture, bacterial cell density, and species. Most of these species require salt except for the two nonmarine luminescent bacteria (5).

In a book entitled "A Complete History of Luminescence from the Earliest Times until 1900," E. Newton Harvey mentioned that with so much experimentation with luminescent bacteria, it was a good thing these bacteria were not pathogenic to man. Harvey also noted that in 1889, P. Tollhausen conducted the first test with luminescent bacteria. He fed his cat some of the glowing "bugs". Since his cat did not experience any ill effects, he sprinkled some of the bacteria on his own food with the same result (2).

Luminescent bacteria exist free living in the ocean, on surfaces and intestines of fish, shellfish, as well as symbionts with various marine fish and squid (6). For example, *Photobacterium* species are found in specialized light organs of teleost fish. *P. phosphoreum* bacteria are present in deep sea fish while *P. leiognathi* have been detected in tropical and temperate fish (7). There are nine marine luminescent species of bacteria, *Photobacterium phosphoreum, Photobacterium leiognathi, Alteromonas hanedai, Vibrio logei, V. fischeri, V. harveyi, V. splendidus I* (3, 5), *V. vulnificus VVLI* (8), and *V. orientalis* (11). Most luminescent bacteria grow at 30°C to 40°C. *P. phosphoreum , V. logei, V. splendidus I, Alteromonas hanedai* (5), and *V. orientalis* (11) can grow at 4°C to 20°C.

Previously, all luminescent bacteria were considered to be harmless to humans (2). In 1986 Dr. James Oliver of the University of North Carolina at Charlotte reported on a bioluminescent strain of *V. vulnificus VVLI.* This microorganism was isolated from a 72 year old man who had received a puncture wound in his leg while

cleaning fish on the Gulf of Mexico. This man died thirteen days later after being admitted to a hospital. This was the first report indicating that a strain of the pathogen *V. vulnificus* was bioluminescent (8).

There are two nonmarine species of luminescent bacteria, *Xenorhabdus luminescens* (5, 12) and *Vibrio cholerae* biotype *albensis* (5); and *Xenorhabdus luminescens* has since been identified as a nonmarine luminous bacterium with strains that are symbionts with terrestrial nematodes of the genus *Heterorhabditis.* It is pathogenic to certain lepidoptera and coleoptera and has also been isolated from a human wound (1, 5,10). *V. cholerae* biotype *albensis* is a non-01 strain of *V. cholerae* and considered a human pathogen. However, there have been no reports of human infections from this strain (8).

Consumer Complaints from 1989 to 1998

The FDA microbiology laboratory, located in Bothell, WA., began analyzing consumer complaints of seafood that glowed in the dark in 1989. During 1989 and 1990 there were seven complaints and five inquiries from the states of Alaska, Arizona, California, Florida, Kansas, Minnesota, and Washington. In all cases the consumers were in the dark when they noticed their seafood products glowing. The various situations included refrigerators with burned out light bulbs, imitation crab meat sandwiches about to be eaten as a midnight snack, imitation crab meat used as pet turtle food, and in cooked and peeled shrimp fed to cats as a special treat (9). *P. phosphoreum* was isolated from five of the seafoods submitted for analysis and *V. logei* was isolated from the other two. There were no illnesses associated with the seven seafood products analyzed.

Four seafood products were submitted to the Bothell FDA laboratory in 1991 for analysis. In February, a consumer in Santa Barbara, California purchased raw red snapper fillets for dinner. She cut the ends off the fish and put them into her cat's dish and cooked the rest. In the middle of the night she got out of bed to put her cat outside and noticed the fish in her cat's dish emitted a green iridescent light. *P. phosphoreum* and *V. logei* were isolated from the raw fish.

In Winchester, New Hampshire, a romantic candlelight dinner was ruined when the husband looked down at his imitation crabmeat salad and green pinpoints of light shimmered back at him. His wife contacted FDA, but decided not to send the salad in for analysis. She conducted her own experiment by feeding the seafood salad to their cat. The cat lived! She concluded her husband would survive. This seafood salad was purchased in bulk from two separate manufacturers by the grocery store.

From 1989 to April of 1991, none of the consumers had experienced any illnesses from eating seafood that glowed in the dark. In May 1991, a consumer in Edmond, Oklahoma purchased a package of imitation crabmeat. This was part of their Sunday night dinner. After dinner she noticed the remainder of the crabmeat glowed in the dark. Monday afternoon she developed stomach cramps and headache. Her husband experienced the same symptoms Monday evening, but they did not seek medical attention.

Since there were illnesses associated with this imitation crabmeat, it was analyzed for luminescent bacteria and for the following pathogens: *Listeria monocytogenes, V. cholerae* and *V. vulnificus. P. phosphoreum* and *L. monocytogenes* type 1 were isolated from the imitation crabmeat.

Another incident involved a seafood salad comprised of imitation crabmeat, imitation lobster meat, salad shrimp plus chopped vegetables and mayonnaise. *P. phosphoreum* was isolated from this seafood purchased in Cincinnati, Ohio.

Imitation crabmeat glowed in the dark in Yakima, Washington. The grocery store had purchased two and a half-pound packages of imitation crabmeat, cut and repackaged them into consumer size portions. *V. logei* was isolated from this crabmeat.

In 1992 six consumers sent their glowing seafood products to the Bothell FDA laboratory for analysis. The

imitation crabmeat from Maryland contained *V. logei*. The raw pacific rockfish from Seattle, Washington contained *P. phosphoreum* and *V. logei*.

A consumer in Chicago, Illinois ate imitation lobster meat. Later that evening he noticed the styrofoam tray he had tossed into his kitchen sink glowed in the dark. He developed stomach cramps and diarrhea 12-18 hours after consuming the lobster meat. He went to a hospital emergency room for treatment. However, no pathogens were isolated from his stool sample. The FDA laboratory in Bothell, Washington isolated *L. monocytogenes* type 1, *P. phosphoreum*, and *V. logei* from the leftover imitation lobster meat on the styrofoam tray.

Some consumers in Aberdeen, WA., purchased imitation crabmeat for snacks and ate some while watching television in bed. The consumer's husband saw a bright green light that emanated from his hand when he picked up a piece of crabmeat that had fallen on the bed. The couple became nauseated four hours after consumption of the crabmeat followed with diarrhea six hours later. The consumer's wife complained of fever and chills. The imitation crabmeat submitted for analysis was dehydrated, weighing less than an ounce, and therefore, was not analyzed.

Raw inshell shrimp glowed in the dark kitchen of a consume in Cumberland, Rhode Island. *P. phosphoreum* was isolated. Another incident involved imitation lobster meat from Chicago, Illinois from which *P. phosphoreum* and *V. logei* were isolated.

In April of 1994 at a restaurant in Atlanta, Georgia, the day cook boiled two and a half pounds of raw peeled shrimp for approximately twelve minutes in boiling water with a small amount of salt. Most of this cooked shrimp was served to customers with a small portion left over, which was placed in the walk-in refrigerator. Later the restaurant chef turned off the light in the walk-in refrigerator and noticed that the cooked shrimp were glowing. Two days later more shrimp were boiled and about four ounces were left and placed into a container in the walk-in cooler. These shrimp also glowed. The FDA investigator collected the remainder of the cooked shrimp from both days plus some of the raw peeled shrimp, purchased from a company in Alabama. *P. phosphoreum* was isolated from both samples of cooked shrimp, but not from the raw shrimp. Since *P. phosphoreum* doesn't survive boiling, it was assumed that the cooked shrimp were cross-contaminated from another source.

Another product submitted in 1994 for analysis was cooked shrimp shells from Metamora, Minnesota. The consumer purchased the cooked shrimp from a grocery store, remove the shells and ate the shrimp. Later that evening she notice the shells glowing in the dark in her trash container. Employees at the grocery store cooked and prepared shrimp platter for their customers. *P. phosphoreum* was isolated from the consumer's shrimp shells.

In Seattle, Washington cooked shrimp purchased from a grocery store in 1996 startled a consumer who opened her refrigerator door. The light bulb had burned out in her refrigerator and the shrimp lit up its interior. *P. phosphoreum* was isolated.

In 1997 imitation lobster meat purchased in Trevor, Wisconsin, lit the consumer's path to his mailbox as he nibbled. *P. phosphoreum* was isolated.

In April of 1997, The Environmental Protection Agency in Seattle, Washington asked the Bothell FDA laboratory to help The Confederated Tribes of the Warm Springs Reservation of Oregon. Their ceremonial king salmon were glowing in the dark. They assumed this was due to radiation and their people were afraid to eat the salmon. They submitted 10 whole king salmon weighing twenty to thirty five pounds each. The salmon were caught from various locations from the Hood River. *P. phosphoreum* was isolated from the skin, intestines, and gills from most of the salmon analyzed.

A unique situation occurred in January, 1998. During a severe ice storm in Maine the electricity went out. The manager of a sardine cannery could not initiate any form of clean up without power. He left the raw herring on the conveyor belts for five days. One evening thereafter, he noticed the fish glowed so brightly that he could have read a newspaper.

In Seattle, Washington a consumer purchased a package of imitation crabmeat after the sell-by date on the label from a grocery store. The store had put the outdated crabmeat on sale. The consumer made an evening snack, which consisted of this crabmeat on a piece of bread with barbecue sauce over the top. He noticed his food glowed in the dark. *P. phosphoreum* was isolated from his open faced sandwich.

Discussion

There were two incidents where *L. monocytogenes* type 1 was isolated from ready to eat products in which bioluminescent bacteria were also detected. These seafood products were imitation crabmeat purchased in Edmond, Oklahoma in 1991 and imitation lobster meat purchased in Chicago, Illinois in 1992. The consumers experienced stomach cramps, diarrhea and headache. Since the consumers in the first instance did not go to a doctor and no pathogen was isolated from the second consumer, there was no evidence that *L. monocytogenes* isolated from the seafood products was causing the illnesses. However, *L. monocytogenes* is a pathogen, that can produce flu like symptoms, abortions in pregnant women, meningitis, septicemia, endocarditis, primary bacteremia, or death in immunocompromised people with AIDS or cancer (4).

In the case of the luminescent bacteria isolated from cooked and peeled shrimp from the restaurant in Atlanta, Georgia, the cooked shrimp might have been cross-contaminated by the chefs or perhaps the bowls used were not properly cleaned. Boiling the shrimp kills the luminescent bacteria and pathogens, which indicates contamination after cooking might have occurred.

FDA investigators visited the grocery stores where some of the ready-to-eat seafood products were purchased. They noticed raw shrimp and raw fish were positioned in front of a ready-to-eat seafood salad in the display case. The drip from the shrimp or fish into the seafood salad could possibly inoculate the salad with luminescent bacteria, and also pathogenic bacteria such as *L. monocytogenes.* They observed that the counter where raw fish was packaged was improperly cleaned before the ready-to-eat imitation crabmeat was cut and repackaged. They watched while employees failed to wash their hands in between handling raw fish and imitation crab meat.

Another example noted in a seafood display case was a beautiful crystal bowl of cooked and peeled shrimp with raw shrimp draped all around the top of the bowl. Liquid was observed dripping from the raw shrimp onto the cooked shrimp. *Salmonella* has been isolated from raw shrimp by the various FDA laboratories across the United States. There is also the possible hazard of other pathogens such as *L. monocytogenes, V. cholerae, V. vulnificus,* and *V. parahaemolyticus* contaminating cooked seafood and causing illness.

Luminescent bacteria occur naturally in seawater, fish, shellfish, and marine animals (5). These bacteria may be present on raw seafood products in the grocery store. They should not be present on cooked seafood products, since cooking destroys these bacteria and other pathogenic bacteria. Employees should follow good manufacturing practices and sanitation in fish markets and grocery stores to prevent cross-contamination of cooked seafood products such as seafood salads, cooked and peeled shrimp, and imitation crabmeat. Good sanitation practices would probably have kept the cooked seafood from being cross-contaminated in most of the incidents where *P. phosphoreum* and *V. logei* were isolated.

Thus far, *P. phosphoreum* and *V. logei* have not caused any illnesses. The only luminescent bacteria that are considered pathogenic are *V. vulnificus VVLI* and *V. cholerae* biotype *albensis* (8).

If any seafood products glow in the dark:

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Patricia Sado has been a microbiologist with the United States Food and Drug Administration since 1968. She started working with luminescent bacteria in 1989 when there had been several consumer complaints. Pat devised an enrichment broth and an agar for isolation of the bacteria and would like to find a better agar to eliminate the competitors.

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