An unaddressed issue of agricultural terrorism: A case study on feed security[1]

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ABSTRACT: In the late winter of 2003, a number of livestock animals in the Midwest were poisoned due the accidental contamination of a popular commercial feed with a lethal additive. Although all the evidence indicates this incident had no malicious or terrorist intent, it is informative as a case study highlighting potential security implications with respect to a terrorist event directed at U.S. agriculture.

Key Words: Agroterrorism, Alpacas, Feed Contamination, Feed Security, Poisoning, Terrorism

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Introduction

Agricultural terrorism is specifically addressed in materials captured in U.S.-led Afghanistan campaigns against the al-Qa'ida terrorist network. This emphasizes that agriculture is a priority target of terrorists. Targeted introduction of a chemical agent harmful to livestock is an area of agricultural terrorism that has not received similar attention as infection with pathogenic zoonotic diseases (e.g., Foot-and-Mouth Disease [**FMD**], African Swine Fever or Rinderpest). In this article, we report a case of livestock poisoning via introduction of a toxic chemical to the feed, examine significant historical cases, and review current policy and thinking with regard to agricultural terrorism directed at livestock.

Animal agriculture may be one of the easiest targets because large mills can be sabotaged as a point source with extremely wide distribution of a poisonous chemical agent in a very short period of time and with extremely severe losses in an extremely short period of time. The current case example (multifarm toxin from a point source mill) and historical examples show that 1) feed mills should be included in homeland security considerations, 2) animal scientists should consider closely poisons suited to feed and water point source contaminations, and 3) advanced planning sessions should be undertaken to develop rapid field test strategies for analysis and response. In the current example, four different laboratories were used and toxin results were not available until 5 d later for the fastest and 3 wk later for the slowest laboratory. Animal scientists may well be the first line of defense in agroterrorism, just as veterinarians are the first line of defense against foreign animal disease. Consequence planning and management must incorporate as wide a range of threats as possible. Although contamination of livestock feed is hardly an unprecedented event, it needs to be brought into the agricultural terrorism dialogue.

History

The intentional introduction of a poisonous additive to the food supply of livestock animals is a potential means for executing a terrorist attack aimed at a state's agriculture. Historically, cattle have been targeted for such terrorist activity. During World War II, the British prepared and tested over five million anthrax-infected "cattle cakes" that could be airdropped onto German cattle fields (Rosie, 2001). In opposition to British rule, a Kenyan group, the Mau Mau, allegedly injected British-owned cattle with a plant toxin and employed arsenic in the early 1950s (Carus, 2001). In March 1970, Ku Klux Klan (**KKK**) members are reported to have poisoned cattle belonging to black farmowners in Alabama. Intending to intimidate and economically menace the ranchers, the KKK contaminated the water supply with a cyanide salt, resulting in the death of thirty cattle and the sickening of nine others (Cameron and Pate, 2001).

One of the first widely reported instances in which cattle feed was intentionally contaminated occurred in 1981 (Neher, 1999). An unknown individual vitiated the entire contents of a farm silo filled with cattle feed using one bag of organophosphate-based corn rootworm

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insecticide. Fifteen years later, also in rural Wisconsin, chlordane, an organochlorine pesticide, was intentionally added to rendering plant material that was then distributed to major animal feed producers (Neher, 1999; Schuldt, 1999). Tainted feed was identified as having been distributed to over 4,000 farms, principally dairies, and led to recalls in four Midwestern states of products including cheese, butter, and ice cream that were suspected of contamination. The action level for chlordane is parts per billion. The charged suspect was a competitor of the targeted facility. The cost to the feed producer alone was estimated at over $250 million. Five months later in May 1997, the same individual allegedly contaminated feed used for poultry with a fungicide (Neher, 1999). In both cases, letters were sent to customers indicating that tampering had taken place. Until the individual charged was detained, additional threatening letters indicating an elevation in activities were received by the affected company and its customers. More recently, more than 250 cattle at an east-central Nebraska feedlot were poisoned with insecticide-contaminated feed (Beck, 2003). Although the specific motivation has not been determined, intentional introduction of a neurotoxic organophosphate compound to a feed wagon is suspected. The estimated financial loss exceeded $130,000.

The long-term effects of accidental feed contamination in one prominent case are still being calculated and felt by people. In 1973, a packaging mistake lead to the incorrect labeling of polybrominated biphenyl (**PBB**) fire retardant as a nutritional feed additive, magnesium oxide, sold as Nutrimaster (Michigan Chemical Co., St. Louis, MI) (Carter, 1976; Dempsey, 2002). The following year, the birth of deformed or stillborn calves, which were initially regarded as the problem of a single farmer, along with decreased milk production, prompted an investigation that eventually revealed the error (Reich, 1983). Over the next 2 yr, 1.5 million chickens, 30,000 cattle, 5,900 pigs, and 1,470 sheep were slaughtered. In the ensuing years, increased incidence of digestive cancers and lymphoma (Hogue et al., 1998), breast cancer (Henderson et al., 1995), and precocious puberty (Blanck et al., 2000) have been documented in those most highly exposed to animals fed with the PBB-tainted feed. The risk level associated with PBB is at the parts per billion level.

Another, more recent case of accidental contamination with tremendous economic consequences and political ramifications occurred in northern Europe. In late winter 1999, poultry farmers in Belgium began reporting sharp decreases in egg production, chicks exhibiting abnormal developmental behavior, and instances of unexpected death, predominantly due to eggs failing to hatch (Bernard et al., 1999; Crawford, 1999; Lok and Powell, 2000). Dioxin-contaminated feed originating from a single producer of fat for animal feed was found to be the cause. Apparently, one single storage tank had been contaminated. The incident prompted a U.S. ban on all chicken and pork from the European Union; trade suspensions and warnings with respect to other European foodstuffs were issued by over 30 governments around the world. The estimated financial impact exceeded $1.5 billion (Reuters, 1999; Lok and Powell, 2000). Three cabinet-level ministers from Holland and Belgium resigned, and the Belgium Premier lost his June 1999 reelection bid. The official source of the dioxin has not been conclusively determined. The European Union's Standing Veterinary Committee did not issue an "all-clear" on dioxin contamination until April 2000.

Today, the focus in agroterrorism defense of livestock is almost completely on the introduction of zoonotic pathogenic organisms and toxins. Many insightful and nonalarmist high-profile articles contain no reference to potential for harm via introduction of lethal chemical poison to livestock (Brown, 1999; Bredow, et al., 1999; Chalk, 2001; Gewin, 2003).

Furthermore, the use of contaminated feed is not limited to chemical agents only. Arguably the most successful use of a pathogen against livestock with criminal intent involved literally homogenizing tissues of animals infected with rabbit hemorrhagic disease, caused by rabbit calcivirus, and mixing it with corn, grains and carrots as feed. The lethal mix was spread by allowing rabbits to eat at will (Carus, 2002). Frustrated farmers found that spreading the disease via contagious animals was taking too long; contaminated feed, dubbed "rabbit smoothies" by one New Zealand journalist, was determined to be more efficient. The case vividly illustrates the ease and effectiveness of using animal feeds as fomites to infect with a biological agent.

The majority of the cases outlined above involved accidental or criminal rather than terrorist intent. Because the primary motivation for terrorists targeting of agriculture is considered to be economic and social disruption and interruption, such terrorism is most likely to be directed at developed nations (Cameron and Pate, 2001). What type of terrorists might attack a food supply? A number of states, including the United States, via its disbanded offensive biological weapons program have or are alleged to have incorporated antilivestock agents into their offensive biological weapons schemes (Alibek, 1999; Carus, 2002; Davis, 2004). International terrorist groups, including al-Qa'ida, are suspected of pursuing the U.S. food supply (Anderson, 2003; Fabi, 2003). Domestic militant antigovernment or antigenetically modified food groups may also be an agricultural terrorism risk (Kentworthy, 2001; Ackerman 2004).

Salinomycin Poisoning of Alpacas

The accidental poisoning of alpacas by feed contaminated with a lethal additive serves as a case study to shed light to an area of the terrorism dialogue that has been pushed to the wayside. What is presented herein intentionally does not provide specific details for larger market animals (i.e., cattle, poultry, and swine), but rather focuses on an exotic animal, the alpaca, that is unlikely to be a terrorist target. In this age of heightened security awareness, the authors are conscious of the need to not inadvertently provide knowledge to those who would use it with malfeasant intentions. The salinomycin poisonings of alpacas, although emotionally and economically damaging to the alpaca breeders and owners, represent a limited threat to the overall U.S. economy. A similar incident with other livestock animals would be a very different case.

Narrative of the Alpaca Poisonings

In March 2003, approximately 1,000 alpacas were unknowingly fed varying amounts of a commercial feed to which salinomycin had been accidentally added at the poultry feed rate, 66 ppm. On the third day of feed consumption, several alpacas demonstrated clinical signs of muscle tremors, weakness, diarrhea, and acute death. Blood analysis was consistent with rhabdomyolysis, the breakdown of muscle fibers resulting in the release of creatine kinase, myoglobin, and organic acids from tissue into the bloodstream. Two farms (designated Farm A and Farm B) reported two deaths from acute fatal rhabdomyolysis on subsequent days. Based on the diagnosis of rhabdomyolysis due to ionophore poisoning, all grain supplies was stopped after d 2 on Farms A and B.

On d 3 through 15, acute deaths were observed on the two farms at a rate of 5 to 17 deaths per day. By d 5, decreasing rhabdomyolysis was noted. Increasing myocardial failure and pulmonary edema, however, were observed.

Clinical signs progressed to primarily cardiopulmonary signs by d 7, and acute deaths at that time were attributable to myocardial degeneration. Deaths and new cases diminished beginning 15 d after onset of the point case, but fatalities associated with myocardial degeneration were observed as late as 3 mo after feed consumption. The poisoning caused 135 alpacas deaths; approximately 250 alpacas displayed clinical signs. Estimates of salinomycin intake were determined to be between 0.5 and 1.5 mg/kg of BW consumed by those displaying clinical signs (estimated overall feed intake was 0.227 to 0.454 kg per animal daily). Six to eight farms were affected, with a combined population of approximately 2,000 alpacas.

Timeline of Poisoning Incident

On d 1, Farm A had one case of acute fatal rhabdomyolysis; on d 2, Farm B had one case of acute fatal rhabdomyolysis; on d 3, Farm B had five cases, and Farm A had two cases acute fatal rhabdomyolysis; on d 4 to 5, there were 5 to 10 deaths per day; on d 6, ionophores screened positive for salinomycin; on d 6 to 10, there were 7 to 17 deaths per day; on d 10, salinomycin contamination concentration was found to be 66 ppm; on d 11 to 20, there were one to five deaths per day; and on d 21 to 90, there was zero to one death per week.

A comparison of Farm A and Farm B revealed no similarities in water table, hay, stock, grass, staff, or veterinarian. The two farms were located in different geographic regions. There had been no direct contact between staff or visitors from the two farms during the previous two months. The only commonality found was the source of one commercial "crumble" feed. Examination of feed bags indicated that Farm A had one batch number, whereas Farm B had three different batch numbers, one of which was the same as found at Farm A. All three batches were subject to analytical testing for presence of mycotoxins, ionophores, and nutrients.

On d 6 an initial ionophore screen, performed by Texas A&M University, indicated the presence of salinomycin. Confirmation tests were performed at multiple laboratories, including the University of Illinois, College of Veterinary Medicine Toxicology Laboratory. The concentration of salinomycin was quantitatively determined to be 60 to 90 ppm, which roughly corresponds to the poultry feed additive level (66 ppm).

Method of Alert and Communication

In cases of food poisoning, whether livestock or human, timely and accurate information dissemination is essential. On d 3, an emergency message was sent to Farms A and B that a single batch of feed was the likely cause of poisoning. These farms circulated electronic mail and phone messages to all clients and to the National Alpaca Breeding Association, which also distributed a cautionary electronic e-mail. On d 4, The Ohio State University (**OSU**) released a cautionary statement recommending against giving any feed purchased within the last 2 mo that originated from a single company until results of analytical tests were known. The Ohio Department of Agriculture and the Ohio state veterinarian were notified, along with consultations with the official state toxicologist and pathologist. The OSU distributed an electronic message to a list of approximately six hundred alpaca and llama farms. On d 14, the Ohio Department of Agriculture confirmed the salinomycin poisoning diagnosis and issued a recall of the contaminated feed.

Informal internet-based e-mail groups were the main method for communication to alpaca owners and breeders. Among the electronic distribution lists of the National Alpaca Breeding Association, Farms A and B, and OSU, approximately 1,000 farms were notified within 12 h of recognition of a source (the commercial "crumble" feed). It is estimated that this prompt action prevented over 500 additional animal exposures. The small size and closely knit nature of the alpaca community enabled such rapid and informal distribution of information. The lines of communication were open and forthright. There were limited constraints on transparent communication due to intellectual property and larger commercial concerns.

Salinomycin: Intended Use and Physiological Effects on Alpaca

Salinomycin is a wide spectrum antibiotic used to prevent coccidiosis in poultry, cattle and, swine due to infection by a variety of *Eimeria spp*. Salinomycin is usually delivered as the sodium salt of the polyether monocarboxylic acid. It is a lipid soluble ionophore. Salinomycin inhibits gram-positive bacteria by interfering with ion transport across cell membranes. In addition to being fatal to New World camelids (llamas, guanacos, and vicunas, as well as alpacas), contraindications exist for horses and dogs.

Discussion

There are 47,952 registered alpacas in the United States (as of September 1, 2003; The Alpaca Registry, Inc., Kalispell, MT); almost 400 animals were poisoned. Of the animals affected, approximately 135 died (or 0.3% of all alpacas in the United States). The estimated economic impact of the poisonings exceeded $6.7 million in dead and damaged animals. Additional potential losses of income not contained in that figure include the cost of lost pregnancies, loss of future offspring, and loss of sire fees.

Although the percentage of alpacas affected was small, if a similar percentage of beef livestock were poisoned, it would correspond to a loss of over 400,000 cattle (information current through 2002; California Beef Council, Pleasanton, CA). Over 75% of the nation's beef cows pass through 2% of the feedlots (Ban, 2000; Horn, 2000). The concentration of animals is dramatic in these lots, with 50,000 to 800,000 cows brought together for the express purpose of feeding them before slaughter (Dunn, 1999). Dairy farms generally have a minimum of 1,500 cows, although the larger farms have upwards of 10,000 animals (Chalk, 2001). Many poultry farms have up to a million birds (Dunn, 1999); swine farms have 10,000 hogs or more (FEMA, 2002). In contrast, the largest alpaca farms have 1,200 to 1,600 animals; most farms are considerably smaller (200 or fewer animals). Therefore the number of animals subject to exposure at a single alpaca farm is small in comparison to beef cattle, dairy cows, poultry, or pigs. One of the alpaca farms affected by the poisoning incident suffered 90 fatalities, which represented approximately 7% of the herd. Due to winter weather conditions, the animals were separated and only a limited number were fed the contaminated commercial feed.

In the Belgian dioxin-contaminated feed case, a small percentage of total cattle farms were affected. Nonetheless, those affected ranches were large agribusinesses and represented a significant percentage of the overall cattle supply (North, 2000). The contamination of one single source affected numerous basic dietary staples.

Frequently, the idea that large quantities of chemicals are required to generate toxic effects is mentioned as a factor contributing to limited terrorist utility of chemical agents in comparison to biological agents. The primary case outlined here (the salinomycin poisonings) produced fatalities at the parts-per-million level; two cases mentioned (chlordane and polybrominated biphenyls) were deleterious at parts-per-billion levels. Given the analytically determined values, as little as 0.5 mg/kg of BW (or approximately 50 to 150 mg) of salinomycin is fatal for an alpaca. One 22.7-kg bag of feed contaminated with 1% salinomycin could hypothetically kill more than 2,250 alpacas, which is a figure larger than any single U.S. alpaca herd. Tanker truckloads of chemicals are not needed; small amounts could have disastrous effects.

Adulteration with a toxic industrial chemical or other poisonous additive to the feed supply is much less sensationalistic than use of exotic bacterial pathogens. Just because a means is "simple" and uses material that is an everyday part of agriculture (commercial feed), does not mean that it should be ignored as a possible terrorist methodology. Although not spreading infectiously, failure to control and collect poisoned feed will result in diffusion to other animals and potentially to humans. This risk needs to be incorporated into the agricultural terrorism dialogue. Similarly, just because a methodology has not yet been used by a terrorist group is no longer a reason to dismiss it. Mass killing of large number of animals at a feedlot or large poultry producer is arguably simpler, cheaper, and more reliable than using a pathogen. The issue of reliability and requisite level of expertise, along with other crucial limiting factors, is illustrated by the distribution of large volumes of weaponized *Bacillus anthracis* spores by the Japanese doomsday cult, the Aum Shrinrikyo, from a Tokyo highrise over 3 d in June and July 1993 (Takahasi et al., 2004). The Aum Shrinrikyo had obtained the Sterne 34F2 vaccine strain rather than a pathogenic strain. The scientists that were part of the Aum Shrinrikyo terrorists had failed to verify the pathogenic nature of the bacteria.

Furthermore, as chemical compounds (rather than fragile microorganisms), the storage, transportation, and time between contamination and release to an animal population are much less complicated than with most infectious biological agents. The notable exceptions are sporulated bacteria, such *Bacillus anthracis*. Weaponizing bacteria and viruses requires a terrorist to have access to sophisticated equipment and trained personnel (Ingelsby et al., 2002; Matsumoto, 2003). Viruses and nonsporulating bacteria are more difficult to grow, to surface modify, and to process into a weaponized form in comparison to sporulating bacteria such as *B. anthracis*. As outlined in the History section of this article, contaminating feed does not pose any of the technical limitations associated with pathogens. Killing of livestock is not the only threat: adulteration of products for other animal or human consumption may make them unsuitable for the marketplace.

The Federal Emergency Management Agency's (FEMA) "Toolkit for Managing the Consequences of

Terrorists Incidents" defines agroterrorism as "the malicious use of plant or animal pathogens to cause devastating disease in the agricultural sector" (FEMA, 2002). Arguably a plant- or animal-based toxin could be included within that scope (although the document does not delineate any toxins in its list of threatening agents). It is worth noting that two of the three cases selected to illustrate previous incidents of agroterrorism in the United States involved the intentional use of a chemical agent: the alleged use of cyanide by KKK in Alabama and the pesticide contamination of feed products in Wisconsin. The third event is a highly suspect accusation from 1996, in which an outbreak of Florida citrus canker was declared to be the result of Cuban biological weapons program. No evidence to support the allegation is available in the open literature. The case occurred at the same time that the Cuban government lodged a formal international complaint against the United States, alleging the it was responsible for infestations of the insects causing Thrips palmi disease, which can devastate tobacco leaves among other crops (Zilinskas, 1999).

An examination of terrorist incidents directed at agriculture was accomplished using the Weapons of Mass Destruction (**WMD**) Terrorism Database maintained and updated by the Chemical and Biological Weapons Nonproliferation Program with the Center for Nonproliferation Studies (CNS) at the Monterey Institute of International Studies (CNS, 2004). The WMD Terrorism database is the largest collection of information on chemical, biological, radiological, and nuclear terrorist incidents based on nonclassified literature. Included in the database are over 1,150 incidents of actual use, threats, hoaxes, and interrupted attempts to use an agent that had been acquired.

Thirty-one cases of terrorism involving agriculture are found in the WMD Terrorism Database as of March 2004. Of the cases, 20 were directed toward crops and foodstuffs (a majority of which involved threats or actual incidents in which foodstuffs were injected or intentionally contaminated with a chemical agent) and 10 at livestock. (One case was an unspecified threat to agriculture.) Of the cases targeting livestock, five involved infectious biological agents, and four used a chemical agent to kill cattle or water buffaloes by poisoning the water or feed supply. One case involved the use of an isolated plant toxin, in which it was more akin to a poisonous chemical than an infectious agent. The lethal chemicals used against livestock include arsenic, an unspecified cyanide salt, rat poison, and insecticide. All the cases involving chemical agents directed at livestock reportedly resulted in fatalities, excepting one incident that was interrupted because the perpetrator alerted the authorities to the successful contamination, whereas none of the terrorism cases involving biological agents has resulted in confirmed fatalities. Of the biological incidents, one was a hoax perpetrated by an imprisoned individual, one was the accusation made by Cuba against the United States, one was an allegation of use of glanders by the Soviets against the Mujahadeen in Afghanistan, and the last had an unknown effect (World War I attempts to disseminate anthrax and glanders). None of the cases involved traditional military chemical agents such as sulfur mustard or sarin nerve agent. All involved dual-use chemicals (i.e., chemicals that have legitimate uses but can also be used for malevolent purposes).

In the Bioterrorism Act of 2002, nothing is mentioned regarding chemical agents in the portion directed toward the USDA ("Subtitle B–Department of Agriculture"; Bioterrorrism Act, 2002). Chemical additives and contaminants are included under areas relevant to the Food and Drug Administration ("Title III—Protecting Safety and Security of Food and Drug Supply, Subtitle A—Protection of Food Supply"). The legislation contains heavy emphasis on inspections at ports of entry: "The Secretary shall give high priority to increasing the number of inspections under this section for the purpose of enabling the Secretary to inspect food offered for import at ports of entry into the United States...." There is no mention of inspection and analytical services at domestic facilities that supply the food for the country's livestock.

The USDA Animal and Plant Health Inspection Service (APHIS) demonstrated an adroit response to the December 2003 confirmation of bovine spongiform encephalitis in a Washington state cow (USDA, 2003; USDA-APHIS, 2004). The Emergency Programs division has been proactive in preparing to respond to both the anticipated and the unanticipated outbreaks of a pathogenic disease in livestock. The FDA is responsible for establishing regulations on livestock feeding. What agency responsible for feed security? Who would be responsible for overseeing control of an incident and subsequent investigation: APHIS or FDA?

Before any government agency would be involved, "first responders" would be called to the scene. In the event of an agricultural terrorism incident, whether by feed contamination or infection with a pathogenic disease, livestock veterinarians would be the first responders. If an exotic animal disease outbreak is suspected, many states have in place integrated animal emergency response plans, which may be supplemented by APHIS' Regional Emergency Animal Disease Eradication Organizations. The U.N. Food and Agricultural Organization (FAO) established an internet-based international warning system for agricultural diseases, through the Global Information and Early Warning System (Global Information and Early Warning System Food and Agriculture Organization, 2004). An expansion of this interactive system—a livestock equivalent of the Program for Monitoring Emerging Diseases (ProMED)—should be investigated. Preparations such as these may serve as models or means by which a feed contamination terrorist incident could be efficiently communicated and handled.

The monitoring of feed composition and implementing a timely response may be easier than responding to an exotic pathogen introduction. One feasible method to increase the level of quality control is via incorporation of process analytics into feed production. Process analytics are the integration of real-time monitoring and continuous sampling instrumentation in the production process (Workman et al., 1999; Gunnell and van Vuuren, 2001). Most commonly applied in industrial chemical and pharmaceutical production and quality control assessment, process analytics may be one discrete improvement for increased agricultural security.

Continued monitoring and rigorous data collection on all animal farms needs to be supported to benefit risk management of both pathogens and feed adulteration. Investment in means to facilitate the rapid sharing of incident reports and verifications of unusual incidents should be sustained. Such a system worked for the alpaca breeders and owners. Following the feed contamination incident many alpaca breeders and owners have started looking at smaller and local feed cooperatives (S. D. Core, Cripple Creek, CO, personal communication). This move toward localization is one means to prevent terrorists from having large targets. It also demonstrates the long-term economic effects that a major feed contamination incident could have. Faith in the quality and safety of not only the specific large company's product but in all products distributed on a major scale has been questioned. Animal owners and breeders are pursuing alternatives to major feed producers.

Implications

There is a critical need to continue proactive research and investment in minimizing and, when possible, eliminating the risk to animals of pathogen-borne diseases. The intention is not to be critical of the overdue focus on pathogenic diseases but rather to highlight an area—feed security—that has been nearly ignored in the terrorist dialogue of the last 3 yr. Is the terrorist threat against U.S. agriculture a strategic threat? The answer is probably not. There is a potential for hugely damaging economic effects, but less so as far as drastic consequences to human life. Analysis and response to both accidental and terrorist use of a poisonous agent against animals must incorporate as wide a range of threats as possible. The historical record illustrates the dire effects of accidental contamination of livestock feed; intentional contamination is one area of the agricultural terrorism discourse that deserves more attention.

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