



the water footprint much smaller. The answer, according to the [available research](#), is, “Beef has a big water footprint no matter how it is produced.” Yet a big water footprint does not necessarily mean it’s unsustainable. Here’s why.

Water footprints are broken out into three parts:

The **green water footprint** (consumption of rain water);

The blue water footprint (consumption of surface and groundwater); and

The grey water footprint (pollution of surface and groundwater).

Regardless of the system in which the animals are raised, most of the water footprint of beef comes from how they’re fed, and more specifically the water it took to grow their feed. While they may start out eating grass, in the United States, approximately **99 percent** of all livestock spends some final portion of their life “finishing” in a feedlot or **concentrated animal feeding operation** (CAFO), where they eat mostly corn- and soy-based feed, along with forage like alfalfa. The other approximately 1 percent continue to graze on pastureland and are given little supplemental feed. Both systems have a very large green water footprint because both rely heavily on rainfall; pastureland grasses and most corn and soy crops are typically not irrigated.

Industrial producers also get a portion of their feed from **irrigated grains**, which enlarge their blue water footprint. Pastureland systems occasionally require irrigation or provide irrigated supplemental feed. This, in turn, expands their blue water footprint. The details of these systems are discussed below.



nitrogen, phosphorus, from fertilizers and pesticides applied to the corn and soy crops and contaminated runoff from mismanagement of cattle manure. Pasture-raised beef have smaller grey water footprints because there is little pollution from runoff of fertilizers and pesticides. (For detailed information about beef production and the benefits of pasture-raised beef, go to the [FoodPrint of Beef](#) report.)

Cattle Feed: Corn vs. Forage

The water footprint of beef is primarily impacted by how much and what the cattle eat, and where the feed comes from. This is because:

Due to their great size, beef cattle eat massive quantities of feed but are **inefficient** in converting that feed to meat (compared to, say, chickens or pigs). More feed = more water.

Across the United States, about **10-15 percent** of corn, about **8 percent** of soy crops and **33 percent** of alfalfa crops are irrigated.

An analysis estimated that about **87 percent** of irrigated US corn is grown in regions deemed to have high or extremely high water stress, which indicates that a significant portion of developed water supplies are already allocated. Located in the American Breadbasket, these vulnerable regions expected to feel the **negative effects of climate change** and currently experience unsustainable groundwater pumping rates and competition over limited water.

Currently, over one third of US corn crop – **36 percent** – is used for livestock feed (including hogs and poultry) and as more livestock is grown in industrial systems, the need for irrigated grains will **increase**.



there is little to no rain, this is can become problematic. Droughts can happen anywhere; for instance, in May 2014, over half of the United States was in some level of **drought**.

Irrigation buffers crops from drought. It also increases crop productivity/yields, and as a result, the percentage of irrigated acres in the United States is **increasing**, even in humid areas.

Cattle Production and Blue, Green and Grey Water Footprints

A direct comparison of the water footprints of industrial and pasture-raised production systems is difficult, because, in the studies done so far by water footprint researchers, data calculations are done using national averages and estimates. Also, different studies use different assumptions and definitions about what makes up each type of system. In addition, there is a lot of variability in how the cattle are raised from country to country, and detailed, US-specific water footprint studies are rare. As such, specific numerical values are avoided in the discussion of the three components of the water footprints for each production system. Because of the dearth of precise data, more general indicators of SMALL, MEDIUM and LARGE are given to gauge the impact that the steps involved in the production system have for each of the blue, green and grey water footprints.

Industrial Systems (CAFOs)

The overwhelming majority of beef produced in the United States comes from CAFOs, sometimes called **factory farms**. (For greater detail on the lifecycle of beef production, see the **EPA Ag101 archive** or the **FoodPrint of Beef** report.) Industrially-raised cattle



open, sometimes pasture-raised environment in what's called a calf-cow operation.

Once they're weaned, they eat grass and forage. Then they're transitioned onto grain feed before being shipped to CAFOs.

CAFOs can contain from a few hundred to up to tens of thousands of head of cattle, which are confined in close quarters. This system evolved to give beef producers a method of maximizing profits by controlling the environment and fattening animals as quickly as possible. Feedlots offer factory-style efficiency and the cattle gain weight quickly by eating specially developed feed comprised of protein- and energy-packed grain concentrate (e.g., corn, soy and grain distillates leftover from biofuel operations). The feed often includes low-dose antibiotics, growth hormones and other supplements to promote faster growth. Feed conversion efficiency is increased, which shortens the time it takes to get cattle to market weight (from a few years down to about 12 months).

High numbers of cattle lead to vast quantities of highly concentrated waste. For instance, a typical beef or dairy cow can excrete about **120 pounds of manure per day** (as much as 20-40 people). A single CAFO, therefore, can produce as much waste as a medium-sized city. The manure is collected in large pools called "manure lagoons," or is applied to fields as fertilizer. Both forms of manure management are known to **pollute** groundwater through aquifer infiltration and surface water through runoff from over-application of fertilizer and lagoon construction failures.

Water Footprint Components of Industrial Cattle:



Footprint comes from the irrigation of specialty formulated feed that uses surface and/or groundwater. Agricultural locations that rely heavily on irrigation for crop production tend to have relatively dry climatic conditions, are more prone to drought and have greater constraints on and demands for surface water and groundwater resources. Competing demands over water resources can spark battles over water rights, allocations and use between sectors, in court and in the larger community.

There are other, minor water uses that add to the blue water footprint, but they are relatively small compared to total. Since most CAFOs get the majority of feed ingredients from offsite sources, water use comes as **virtual water** from offsite production of fossil fuel-heavy (and water-intensive) fertilizers and pesticides and fuel for farming equipment, etc. There are also small amounts of direct water uses such as onsite water required for feed preparation and mixing, animal drinking and facility maintenance.

Green Water Footprint: SMALL-MEDIUM In the early cow-calf stage of production, rainfed grasses and forage are eaten as cattle graze on pasture. Once moved to feedlots, a significant portion of their feed comes from rainfed corn and/or soy crops, depending on where the grain came from.

Grey Water Footprint: LARGE Major indirect water pollution occurs because of farm field runoff of fertilizers and pesticides that were applied to corn and soy crops. Synthetic fertilizers are one of the primary causes of **dead zones** in US freshwater and marine systems.



manure and at large CAFOs, concentrated waste and pollution is a big problem.

Unfortunately, this is the most underestimated component in current agricultural water footprint research (a fact that is readily **acknowledged** by researchers).

CAFO waste is hazardous and can contain antibiotics, bacteria, pathogens and heavy metals. The waste is nutrient-rich, which, in overabundance, contributes to algae blooms in water bodies that create oxygen-depleted “dead zones” that are inhospitable to most aquatic life.

Pasture-Raised (Pastured) Systems

In a **pasture-raised** livestock system, almost all of the animal feed comes from pastures and rangelands where the cattle live. Because a pastured beef cow or steer eats less energy-dense food, the amount of time needed to bring it to market weight and ready it for slaughter (18 to 30 months) is **longer** than for those animals raised in industrial systems.

Since they are relatively free to roam, the number of cattle per land area is low (e.g., per acre, per hectare), which means that manure excreted by cattle – which is prodigious compared to most other animals – is spread out and assimilated into the soil. Manure is nutrient-rich and, in the right amounts, is conducive to plant growth and soil health.

Water Footprint Components of Pasture-Raised Cattle:

Blue Water Footprint: SMALL In general, cattle don't rely on irrigated crops from offsite farms, although many pasture operations supplement with hay during winter



Green Water Footprint: LARGE Cattle rely primarily on rainfed grasses and forage that is grown or cultivated on pasture and rangeland. This more natural diet lengthens the time it takes to get cattle to market weight. The green water footprint is larger but there are significantly less impacts on local water resources.

Grey Water Footprint: SMALL Since the number of cattle per land area is low, less manure is produced and thus, far less pollution from manure runoff is incurred. There is also little to no indirect water contamination resulting from pesticides, fertilizers, growth hormones and other feed supplements found in the industrial system, because these substances are not typically present in the pasture-raised cattle system.

Reducing Water Footprints Through Dietary Changes

It's important to emphasize that CAFOs create other major problems, most notably **air pollution, public health threats, animal abuse** and **adverse socioeconomic impacts**. In terms of the overall degree of sustainability of beef, the water footprint is only one factor, but given the regular occurrence of **water shortages and droughts** on one side, and **intense precipitation and flooding** on the other, the water requirements for specific agricultural products is important and necessary in the United States and around the world.

Unquestionably, a person's diet has a huge environmental impact. The **demand for meat in the United States** remains very high and as it **increases worldwide**, the problems associated with CAFOs – increased demand for feed, irrigation water for crops and pollution from fertilizers and manure – are expected to worsen. This leads to



throughout the country. For instance, heavy agricultural water demands threaten vital water resources like the over-allocated Colorado River and strained Ogallala Aquifer.

One strong response to the question, “How do I lower my water footprint?” is to advise people to eat less meat, and when they do eat it, to choose meat from well-managed pastured sources. People who eat pasture-raised beef and meat might have larger water footprints than those who eat vegetarian or vegan diets. But as the above analysis illustrates, the environmental impact could be reduced if pastured meat is eaten as opposed to meat produced from resource-intensive, environmentally harmful industrial systems. Although arguments for the efficiency of industrially produced beef are often advanced, those arguments often avoid the true costs of meat production systems inflicted on the environment and society, which are often hidden behind those efficiencies.

To gain greater insight about water impacts and water footprints for various beef and meat production systems, from pasture-raised to industrial, more site-specific data from rigorous and comprehensive field studies would be useful.

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Article

The control of blowflies infesting slaughterhouses. 1. Field observations on the habits of blowflies

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Abstract

The habits of blowflies infesting slaughter-houses have been studied to determine the conditions under which control measures are most likely to be effective. Flies found in such numbers as to be considered pests of economic importance were: *Calliphora erythrocephala* (Meig.) and *C. vomitoria* (L.); *Lucilia caesar* (L.), *L. illustris* (Meig.) and *L. sericata* (Meig.); and *Phormia terrae-novae* (R.-D.). All were found breeding profusely on slaughter-house refuse. The reactions of adult blowflies to weather and the working conditions at the slaughter-house are recorded; the three genera react in differing degrees to relatively minor changes in weather conditions, and redistribution of populations caused by these changes is so rapid as to make difficult the accurate assessment of degree of infestation. It was found that blowflies normally do not settle on the internal fabric of slaughter-house buildings but tend rather to congregate on nearby vegetation. The preferences were studied of adult flies for certain types of meat, for particular parts of carcasses, and for meat exposed to sunlight. Conditions favouring rapid development of larvae were determined and the rates of breeding recorded for the three genera when in natural competition and when breeding independently. The larvae of *P. terrae-novae* were found to be predacious on other species and each other. *Lucilia sericata* was found to oviposit and breed successfully in vegetable matter.

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Blowflies overwinter as fully grown larvae which pupate only a short while before emerging in the spring. Various methods are discussed whereby the findings of this investigation into the life history and habits of blowflies can be utilized in the control of these pests.

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... As with other insects, olfactory-mediated behaviours are central to the ecology of blowflies [5][6][7]. Characterised by their larvae's ability to develop on flesh, blowflies have significant roles in forensic entomology [8], agriculture [9][10] [11], and medicine [12,13], and rely heavily on the detection of mammalian decomposition odours. The decomposition process produces a diverse array of inorganic gases and volatile organic compounds (VOCs). ...

... Identification of members of the primary gene families mediating insect olfaction permits a better understanding of the molecular basis of blowfly olfaction. Such knowledge could ultimately lead to the identification of new targets of control strategies [11, 57], an improved understanding of how blowflies recognise, locate, and colonise hosts, as well as improved methods for estimating post-mortem interval [7]. ...

Chemosensory genes identified in the antennal transcriptome of the blowfly *Calliphora stygia*

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Treatment alternatives of slaughterhouse wastes, and their effect on the inactivation of different pathogens: A review

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Abstract

Slaughterhouse wastes are a potential reservoir of bacterial, viral, prion and parasitic pathogens, capable of infecting both animals and humans. A quick, cost effective and safe disposal method is thus essential in order to reduce the risk of disease following animal slaughter. Different methods for the disposal of such wastes exist, including composting, anaerobic digestion (AD), alkaline hydrolysis (AH), rendering, incineration and burning. Composting is a disposal method that allows a recycling of the slaughterhouse waste nutrients back into the earth. The high fat and protein content of slaughterhouse wastes mean however, that such wastes are an excellent substrate for AD processes, resulting in both the disposal of wastes, a recycling of nutrients (soil amendment with sludge), and in methane production. Concerns exist as to whether AD and composting processes can inactivate pathogens. In contrast, AH is capable of the inactivation of almost all known microorganisms. This review was conducted in order to compare three different methods of slaughterhouse waste disposal, as regards to their ability to inactivate various microbial pathogens. The intention was to investigate whether AD could be used for waste disposal (either alone, or in combination with another process) such that both energy can be obtained and potentially hazardous materials be disposed of.

Keywords: Renewable energy, waste treatment, pathogen inactivation

Introduction

An in-depth review of available literature was conducted in order to compare three different methods of disposal of the waste products generated from the slaughtering of animals in abattoirs. The databases Medline and Web of Science were used, and search terms included slaughterhouse wastes, pathogens, composting, anaerobic digestion (AD) and alkaline hydrolysis (AH), as well as pathogen names. In particular, of interest was to determine the safety of using slaughterhouse waste in AD to produce methane, and as a method of disposal of such wastes. Slaughterhouse wastes are animal byproducts, and can contain different bacterial, viral, prion and parasitic pathogens. Composting and AH were also reviewed, with regard to their abilities to eliminate specific pathogens.

Slaughterhouse wastes constitute the inedible parts of animals derived from the production of meat, as well as blood and other animal byproducts. Inedible animal tissues (organs, integument, ligaments, tendons, blood vessels, feathers, bone) can comprise up to 45% or more of the slaughtered animal. The remaining fraction, is, however, not only fit for disposal, and pet food companies are known to purchase large amounts of slaughterhouse wastes. These can be used either alone, or as a supplement for animal feed ([Salminen and Rintala, 2002](#)). Nonetheless, considerable amounts of slaughterhouse waste are produced worldwide, and their disposal poses a serious logistical challenge for meat/poultry processing plants. As a result of such high magnitudes of animal waste, and because of the legal restrictions and rising treatment costs of removal, improper and unsafe disposal of these wastes can occur. Such practices can then also lead to serious environmental problems ([Arvanitoyannis and Ladas, 2008](#)). Slaughterhouse wastes have, however, potential as an energy source, and could help to reduce the requirements of petroleum based fuels currently used for the Earth's energy needs ([Srivastava and Prasad, 2000](#)).

As such alternative energy sources emerge, a number of questions will be asked concerning the safety of the end products generated. In the case of using slaughterhouse wastes in biogas production, the microbial quality of the end product is of major concern as slaughterhouse wastes can be contaminated with high numbers of microorganisms including bacteria, viruses, prions, fungi, yeasts and associated microbial toxins ([Urlings et al., 1992](#)). Such wastes pose a potential risk to animal and human health, unless handled and treated properly.

The management of animal carcasses has always been, and continues to be, a concern in animal production operations, slaughter plants, farms and other facilities that involve animals. Throughout history, burial and to a lesser extent, burning, have been the most commonly applied methods for the disposal of on-farm mortalities ([Gwyther et al. 2011](#)). However, the European Union Animal By-Product Regulation (EC) no. 1774/2002 ([Anon, 2002](#)) does not allow these practices to be conducted within the EU and limits the disposal routes to incineration (either on or off-farm), rendering, high temperature/pressure AH, disposal at maggot farms or through licensed waste collectors ([Anon, 2002](#)). The prevention of disposal by burial and burning was founded based on the perceived risk of an incomplete destruction of pathogens from mortalities during these processes, and thus the entering of infective agents into the animal feed chain ([Anon, 2002](#)). Similar risks are involved upon the slaughtering of animals. In contrast to burning, properly operated incineration facilities pose fewer pollution concerns. Also, bacteria (including spore-formers) and viruses should not survive the incineration process ([NABC, 2004](#)). There are, however, some concerns that transmissible spongiform encephalopathies (TSEs) such as BSE (bovine spongiform encephalopathy) can survive incineration processes if not conducted at a high enough temperature ([NABC, 2004](#)).

Rendering is another method used for the disposal of animal waste products. It involves the conversion of animal carcass/waste materials into three end products, carcass meal (proteinaceous solids), melted fat/tallow, and water. This is conducted using mechanical processes including grinding, mixing, pressing, decanting and separating, thermal processes including cooking, evaporating, and drying, as well as chemical processes such as solvent extraction ([NABC, 2004](#)). The rendering process simultaneously dries the material and separates the fat from the bone and protein. The fat obtained can

be used as low-cost raw material in making grease, animal feed, soap, candles and biodiesel, and tallow is an important raw material in the steel rolling industry providing the required lubrication for compressing steel sheets. The protein meal produced can be used for animal feed. Thus the products provide significant additional income to the slaughterhouse. However, because of the problems with BSE, the feeding of meat and bone meal to cattle is currently prohibited in developed countries. Thus rendering plants do not play as significant a role in the disposal of animal wastes today as they did in the past.

New risks have arisen from the implementation of the European Union (EU) Landfill Directive (EU, 1999) for more environmentally sensitive waste disposal methods. Evidence exists that certain pathogens and pests can survive composting or other waste treatment processes, sometimes through inadequate methods or failures in the process ([Noble and Roberts, 2004](#)). According to the European Union Animal By-Product Regulation (EC) no. 1774/2002, animal byproducts (ABP) are categorized in three classes. ABP of categories 2 and 3 can be treated by approved composting plants and by AD in approved biogas plants, while ABP of category 1 cannot. The guidelines do not stipulate allowances for AH. Most slaughterhouse wastes fall into categories 2 and 3.

This review focuses on three methods that can be used to dispose of slaughterhouse waste: composting, AD and AH. Particular emphasis has been placed on determining the inactivation successes of the three different methods on various bacterial, viral, parasitic and prion pathogens that can be encountered in animal carcasses and slaughterhouse wastes.

Treatment methods

Composting

Composting is an aerobic process by which organic materials are degraded through the activities of successive groups of microorganisms ([Dees and Ghiorse, 2001](#)). Substrates vary, and can include different types of organic and inorganic wastes, sewage sludge, pig, cattle or poultry manure, garden waste and municipal solid waste. The positive effects of composts on arable soil have been reported by many authors ([Ibekwe et al., 2001](#); [Bailey and Lazarovits, 2003](#)).

An efficient and satisfactory composting process is dependent on the presence of a high microbial diversity ([Beffa et al., 1996](#)). Different microbial communities predominate during the four consecutive phases ([Blanc et al., 1999](#); [Alfreider et al., 2002](#); [Ryckeboer et al., 2003](#)) involving mesophilic, thermotolerant, and thermophilic aerobic microorganisms ([Beffa et al., 1996](#)). Continual change in environmental conditions in composts (temperature, pH, aeration, moisture, availability of substrates) results in stages of exponential growth and stationary phases for different organisms. Knowledge on the diversity of the microbial communities of compost is increasing rapidly through the use of molecular biology tools, such as the COMPOCHIP microarray ([Franke-Whittle et al., 2005, 2009](#); [Danon et al., 2008](#)).

Among the concerns regarding the composting process and the use of composts in agriculture and horticulture, however, is the survival and spread of animal, human and plant pathogens. Thus, any composting process must be capable of the elimination of any health risk that may be present in the end product (Strauch, 1996; [Böhnel et al., 2002](#)). An improperly managed composting process can induce the proliferation and dispersion of potentially pathogenic and/or allergenic thermotolerant/thermophilic fungi and bacteria ([Beffa et al., 1996](#)).

Two types of composting systems exist, windrow and in-vessel systems. In-vessel composting has several advantages over windrow composting, namely, that it requires less space, provides better control than windrows, and offers a high process efficiency ([Cekmecelioglu et al., 2005](#)). The higher temperatures achieved however in windrow composting have been found to result in greater bacterial

and pathogen reductions ([Cekmecelioglu et al., 2005](#)). According to [Noble and Roberts \(2004\)](#), the cool zones in in-vessel composting systems where there is no or little turning, are of concern for pathogen survival. Thus, windrow composting of slaughterhouse wastes is the more appropriate approach.

Composting provides an inexpensive alternative and environmentally acceptable method for the disposal of slaughterhouse wastes. The temperatures reached during the decomposition process can kill or greatly reduce most pathogens, thus reducing the chance to spread disease. Although the heat generated during composting results in a reduction of microorganism and pathogen numbers, it is not sufficient to completely sterilize the end product, thus leaving some potential for survival and (re)growth of pathogens. The levels of pathogenic bacteria remaining at the end of the composting process are dependent on the temperatures reached and the time the temperature was maintained. Legal requirements in various countries ask for a minimum temperature of 65°C for at least 6 consecutive days or two 3-day periods >65°C (e.g. [Kompostverordnung, 2002](#)). Achieving an average temperature of 55–60°C for 1–2 days is generally sufficient to reduce pathogenic viruses, bacteria, protozoa, and helminth ova to an acceptably low level. However, the endospores produced by spore-forming bacteria such as *Clostridium* and *Bacillus* would not be inactivated under these conditions ([NABC, 2004](#)). Typically, pH values exceeding 8 are also obtained in the composting process ([Reuter et al., 2011](#)) which also contributes to the inactivation of pathogens. Pathogens in compost can also be inactivated by the action of antibiotics produced by various microorganisms present in the compost ([Hoitink and Boehm, 1999](#)).

Composting can potentially serve as an acceptable method of disposal of slaughterhouse wastes. However, some additional treatments would be necessary to inactivate some pathogens in the end product. Composting can also serve as a method of post-treatment of AD wastes. This post-treatment helps to ensure a more complete breakdown of organic matter, and enriches the compost in terms of the nutrients. Composting of the anaerobic digestate would in addition act to reduce pathogen levels in such products.

AH

AH represents a relatively new technology for the disposal of animal carcass material, and other infectious wastes (Kaye, 2003; [NABC, 2004](#)). The process uses sodium or potassium hydroxide to catalyze the hydrolysis of biological materials (proteins, nucleic acids, carbohydrates, lipids, etc.) into a sterile aqueous solution consisting of small peptides, amino acids, sugars, and soaps. In order to accelerate the hydrolysis, the process is usually conducted with pressure and temperature. For the inactivation of microbial pathogens, carcasses must be heated to 100°C and pressurized at 103 kpa for 3 h. To destroy prion containing material, carcasses must be heated to 150°C and pressurized at 486 kpa for 6–8 h (http://ssl-edss.tamu.edu/disposal/handbook/04_Alkaline.pdf).

Studies investigating the inactivation of pathogens using AH are limited, however, those that exist, indicate the method to be highly successful. [Neyens et al. \(2003\)](#) reported that an AH process conducted at 100°C, pH ≈10, 120 kpa and for 60 min was able to kill all pathogens. Unfortunately, it was not reported which pathogens were investigated. In a recent study, [Dixon et al. \(2012\)](#) investigated the use of AH at ambient temperature for the inactivation of the fish pathogens infectious salmon anaemia virus (ISAV) and *Lactococcus garvieae*. Both pathogens were inactivated after 48 h of treatment with 1 M NaOH at pH >13 and at room temperature. The efficacy of AH as an alternative for the treatment and disposal of infectious waste was also evaluated by testing for the destruction of specific microorganisms in a study by Kaye et al. (2003). AH was found to destroy all representative classes of potentially infectious agents.

The sterile end product of AH can be released into a sanitary sewer, in accordance with local and federal guidelines regarding pH and temperature (Kaye, 2003). Studies conducted by the same authors have shown that by bubbling carbon dioxide into the hydrolysate at the end of the digestion, the pH of the end product can be reduced into the range of pH 8 or less. Considering that the hydrolysate is comprised of a mixture of single amino acids, small peptides, and fatty acids, all excellent growth nutrients for microorganisms (Kaye, 2003), alternative disposal methods for this waste product should be sought. One possibility is its use as a fertilizer ([NABC, 2004](#)), however, another possibility that would require further research, but which would serve in renewable energy production, would be its use in AD. Coupled with AD, an AH unit could produce significant amounts of energy, and at the same time, safely dispose of potentially contaminated slaughterhouse waste products.

An alkaline pretreatment with NaOH was used in a study to enhance biogas production from the AD of corn stover ([Zhu et al., 2010](#)). Different concentrations of NaOH (1–7.5% w/w) were tested and the preparations were subjected to AD. The highest biogas yields were obtained with 5% NaOH. This study shows that AH of slaughterhouse wastes followed by AD should be considered a potential route of treatment.

There are many advantages of using AH for the inactivation of disease agents in slaughterhouse wastes. These include the combination of a sterilization and digestion step into one operation, the reduction of waste volume and weight by as much as 97%, the total destruction of pathogens including prions such as BSE and the lower emission of odors or public nuisances.

AD

AD is a biological process by which organic wastes are decomposed in the absence of oxygen, producing a sludge of agricultural value, as well as biogas, which can be used to generate energy ([Lastella et al., 2002](#); [Insam and Wett, 2008](#)). In recent years, AD technology has been applied and used commercially in the treatment of farm, industrial, and municipal wastes. AD also represents an alternative method for the disposal of animal carcasses and slaughterhouse wastes, with the dual benefits of both eliminating waste material and producing energy ([Insam et al., 2010](#)), thus saving carbon credits. Concerns exist however as to whether an AD process can successfully inactivate pathogens. Often, a pasteurization step is used to help inactivate pathogens prior to AD. It is also common to include a secondary heat treatment process (e.g. composting or pasteurization) and a minimum storage period at the end of the process for the digestate as an additional measure ([Sahlström, 2003](#)). Swedish law for example, requires biogas plants that use animal waste to pasteurize the incoming substrate at 70°C for 60 min prior to digestion, to ensure a hygienically acceptable end product ([Sahlström et al., 2008](#)).

The anaerobic process itself requires specific environmental conditions and requires that the bacteria and archaea involved co-operate in a close and efficient syntrophism ([Schink, 1997](#)). Digestion occurs in four major stages (hydrolysis, acidogenesis, acetogenesis, and methanogenesis) and complex polymers are degraded in a stepwise manner to yield CO₂ and CH₄.

AD can be run either under mesophilic (35°C) or thermophilic conditions (55°C), and the duration of the process and the effectiveness in destroying pathogens thus varies. A mesophilic process will typically run for 15–30 days, while a thermophilic process will run for 12–14 days ([Vandevivere et al., 2002](#)). Mesophilic AD processes are reportedly more robust and less sensitive to changes in process parameters than are thermophilic processes, however, gas production is lower and it is more likely that the end product poses a greater pathogen risk if applied directly to the field ([NABC, 2004](#)). Methane producing microorganisms are more sensitive to temperature alterations than other bacteria, and temperature variations as low as 2°C can reportedly have adverse effects on mesophilic AD processes ([Gunnerson and Stuckey, 1986](#)).

Thermophilic AD on the other hand offers higher methane production, faster throughput, and a better inactivation of pathogens. Despite its advantages, the thermophilic digestion process needs more expensive technology, and requires a higher degree of operation and monitoring ([Vandeviere et al., 2002](#)). Also, changes of only 0.5°C can affect thermophilic AD processes ([Gunnerson and Stuckey, 1986](#)).

[Monteith et al. \(1986\)](#) seeded a bovine enterovirus and parvovirus into liquid cattle manure, and noted that both viruses were rapidly inactivated by a thermophilic AD process, and not detected after 30 min. Under mesophilic conditions, however, the viruses were able to survive for 13 and 8 days, respectively. [Spillman et al. \(1987\)](#) also found that the rotavirus and coxsackievirus B5 animal viruses were rapidly inactivated by thermophilic AD. These findings indicate that viruses are inactivated during AD, but that the rate of inactivation is dependent on the virus, the temperature and the duration of digestion. Even when using a thermophilic AD process, it is advisable to use an additional heat treatment at the end of the process to fully inactivate pathogens capable of surviving AD (i.e. spore-formers). In fact, the European Commission Regulations (EC) no. 1774/2002 and no.208/2006 require a 70°C/60 min pasteurization step of animal waste prior to landspreading of sludges ([Bagge et al., 2005](#)). It should also be remembered however, that an additional heat treatment would still most likely not allow the inactivation of prions such as BSE ([NABC, 2004](#)).

The high lipid and protein contents of slaughterhouse waste products can cause inhibition of AD processes, as a result of an accumulation of ammonia produced from the degradation of proteins and long chain fatty acid accumulation from the breakdown of lipids ([Cuetos et al., 2010](#)). Also, lipids can form floating aggregates and foam that can cause stratification problems due to the adsorption of lipids into the biomass ([Cuetos et al., 2010](#)). However, if properly managed, AD can be conducted successfully on slaughterhouse wastes with high methane production, by allowing a progressive acclimatization of the microbial communities to an ammonia rich medium ([Edström et al., 2003](#)).

Pathogens

In this section, information on the survival and inactivation of a number of specific pathogens or indicator organisms is summarized.

Escherichia coli

Escherichia coli is a Gram negative, rod-shaped bacterium that is often found in the lower intestine of warm-blooded organisms. Most strains are harmless, although there are serotypes that cause food poisoning in humans, and strains such as O157:H7, which can cause serious illness or death in the elderly, the very young and the immuno-compromised ([Sahlström et al., 2003](#)).

A pasteurization experiment was conducted by [Sahlström et al. \(2008\)](#) to determine the survival rates of *E. coli* O157 after heat treatment. In the experiment, *E. coli* O157 was found to survive after 30 min at 55°C, but not after 60 min at 55°C. Similarly, a treatment at 70°C for 30 min was sufficient to inactivate *E. coli*. Inactivation of non-pathogenic *E. coli* and pathogenic *E. coli* O157:H7 has been reported during composting of several types of waste, including animal manure and sewage sludge ([Lemunier et al. 2005](#)). The persistence however of non-pathogenic *E. coli* during composting and the finding of non-pathogenic *E. coli* in mature composts have also been reported ([Lemunier et al. 2005](#)). It is possible that in these cases the composting process employed was not conducted for a long enough time at a high enough temperature.

Laboratory scale experiments conducted by [Jiang et al. \(2003\)](#) have shown that *E. coli* O157:H7 in bovine fecal matter are inactivated at thermophilic composting temperatures. In their study, [Jiang et al. \(2003\)](#) showed that large populations (10^4 – 10^7 CFU/g) of *E. coli* O157:H7 survived for 36 days during composting in a bioreactor at an external temperature of 21°C but were undetectable after 7–14 days of

composting in the bioreactor at an external temperature of 50°C. In another study, [Lung et al. \(2001\)](#) investigated *E. coli* O157:H7 survival after cow manure composting. *E. coli* O157:H7 was not detected after 72 h of composting at 45°C. Thus, a composting process conducted at a minimum temperature of 50°C and lasting longer than a week was assumed to be able to successfully inactivate *E. coli* O157:H7 in manure, and could be assumed to inactivate other *E. coli* strains in slaughterhouse waste products.

The reductions of pathogenic and indicator bacteria (including *E. coli*) in animal slurry subjected to mesophilic (35°C) and thermophilic (53°C) AD was investigated in a study using both small-scale and full-scale reactors ([Olsen and Larsen, 1987](#)). At small-scale digestion at 35°C, a T90 value (time required for a 90% reduction in number of bacteria) of 1·8 days was measured for *E. coli*. At 53°C, the T90 value was reduced to 0·4 h for *E. coli*. Similar values were obtained at full-scale. Thus, we would hypothesize that a combination of a pasteurization step prior to AD, followed by an AD process should totally inactivate all *E. coli* cells present in any slaughterhouse waste material.

No information could be found concerning the use of AH to inactivate *E. coli*. However, considering that AH was found in a study by [Kaye et al. \(1998\)](#) to completely destroy all representative classes of potentially infectious agents as well as disposing of animal carcasses by solubilization and digestion, it can be assumed the process would also totally inactivate *E. coli*.

Salmonella

Salmonella are ubiquitous and cause illnesses such as typhoid and paratyphoid fever, and very frequently, food poisoning. All serovars of *Salmonella* are potentially pathogenic to both humans and animals, and the organism is spread in the environment by animal slurry, and sewage sludge ([Sahlström et al., 2003](#)). *Salmonella* is often used as an indicator organism to test whether a particular treatment process has been successful in the inactivation of microorganisms. Many studies have been conducted investigating the survival of *Salmonella* at various temperatures, for different periods of time. Generally, *Salmonella* is not able to survive at temperatures above 70°C. With the exception of *S. senftenberg*, *Salmonellae* are destroyed at 56°C for 10–20 min, although there is better heat tolerance at low water activity and in high fat foods. In a study by [Paluszak et al. \(2011\)](#), *S. senftenberg* W775 introduced into meat material was found to be eliminated by a composting process within 30 h at 68°C. However, *Salmonella* has been reported to be able to re-colonize composts when temperatures are reduced near the end of the composting process if the process did not reach sufficiently high temperatures, or if the pile was not adequately aerated or turned ([NABC, 2004](#)).

Temperature is the most important factor affecting the survival of a pathogenic microorganism during AD. Studies by [Plym-Forshell \(1995\)](#) showed that *Salmonella* could be inactivated within 24 h in a thermophilic digestion process, while weeks-months were required in a mesophilic digestion process. However, in a study conducted by [Gadre et al. \(1986\)](#), all *Salmonella* species investigated were inactivated after 10 days at 37°C. Pasteurization is frequently used prior to AD in order to reduce pathogen numbers ([Sahlström et al., 2003](#)). As it is known that *Salmonella* in sludge cannot withstand more than 5 min of heating at 70°C, a pasteurization step should act as extra insurance for *Salmonella* inactivation from slaughterhouse wastes and in animal material after AD.

Literature does not reveal much information on the use of AH to inactivate *Salmonella*. A study by [Mastroeni et al. \(1994\)](#) found AH of crude whole *Salmonella* extracts reduced the lethal toxicity of the extracts on mice. Extracts were however only incubated with NaOH at a final concentration of 0.25 M for 3 h at 37°C. This is much lower a temperature than what is used in AH units. Considering this, and that AH was found in a study by [Kaye et al. \(1998\)](#) to completely destroy all representative classes of potentially infectious agents as well as disposing of animal carcasses by solubilization and digestion, it can be assumed that the process would also totally inactivate *Salmonella* species.

Clostridium (botulism, black quarter, tetanus)

Clostridium botulinum causes the disease botulism. The disease can occur following ingestion of contaminated food, from colonization of the infant gastrointestinal tract, or from a wound infection. Vegetative cells and spores of *C. botulinum* can be found in soil, decaying vegetation and manure ([Bagge et al., 2010](#)). The disease results from the production of a potent neurotoxin which is released when spores germinate ([Berge et al., 2009](#)).

Black quarter is an infectious and often lethal bacterial disease of sheep and cattle caused by *Clostridium chauvoei*. The bacteria can be found in soil and faeces ([Bagge et al., 2010](#)), and once a pasture has become contaminated, the disease usually occurs annually in susceptible animals that graze on the pasture ([Timoney et al., 1988](#)).

Clostridium tetani is the causal agent of tetanus, a disease characterized by muscular spasms that can lead to respiratory failure and, in up to 40% of cases, death. Spores of the bacteria can reside in soil or in the gastrointestinal tract of animals. *C. tetani* usually enters a host through a wound to the skin. *C. botulinum*, *C. chauvoei* and *C. tetani* can cause serious diseases in farm animals, resulting in suffering or even death for the animals. Spore-forming bacteria including pathogenic *Clostridium* species can survive pasteurization and are reportedly not affected by the AD process ([Olsen and Larsen 1987](#); [Bagge et al., 2005](#); [Sahlström et al., 2008](#)). [Couturier & Galtier \(2000\)](#) report survival of *Clostridium* following thermophilic digestion. The survival of pathogenic Clostridia during the biogas process results in the need for careful assessment of the risk of application of digested residues onto agriculture. A study by [Bagge et al. \(2010\)](#) however failed to show the survival of pathogenic clostridia after AD.

It has been reported that *Clostridium* can survive the composting process ([Berge et al., 2010](#)). In a carcass-composting environment, it has been found that anaerobic zones do develop, despite attempts to keep the entire process aerobic. These anaerobic zones allow the growth of *Clostridium* cells. Eventually, as decomposition occurs, and the temperatures increase, *Clostridium* growth will slow, and sporulation will occur ([Berge et al., 2010](#)).

The AH process has been shown to destroy all pathogens listed as index organisms by the State and Territorial Association on Alternative Treatment Technologies (STAATT I and STAATT II), which require a 6-log (99.9999%) reduction in vegetative agents and a 4-log (99.99%) reduction in sporeforming agents ([NABC, 2004](#)). Thus, it could be assumed that *Clostridium* would be inactivated through AH, and that AH would appear to be the best approach that could be taken to inactivate spore-forming clostridial pathogens.

Brucella abortus (Brucellosis)

Bacteria of the genus *Brucella* are the causative agents for the zoonotic disease brucellosis. *B. abortus* infects cattle primarily, although it can occasionally also infect sheep ([Bertram-Shaw et al., 1976](#)). *B. abortus* infects the placenta and fetus of gestating cows and causes the fetus to abort. When humans however, are infected by this organism they develop a severe fever, but do not abort ([Corbel et al., 1997](#)).

Bacteria of the genus *Brucella* have been reported to be very heat sensitive ([Van den Heever et al., 1992](#); [Jay, 2000](#)). Pasteurization at 63°C for 30 min and at 72°C for 15 sec successfully removed *Brucella* from contaminated raw milk, making it safe for consumption, indicating that pasteurization of animal carcasses could be used to remove the risk of disease. These findings would also suggest that composting could also inactivate *Brucella*. Similarly, [Harada et al. \(1993\)](#) reported that a temperature of 61°C for 3 min would inactivate *Brucella abortis* or *suis*. It is thus likely that a thermophilic AD process would also inactivate this pathogen.

Again, although no literature reports regarding the survival of *Brucella* after a process of AH could be found based on the report of [Kaye et al. \(1998\)](#), it could be expected that AH would be capable of the inactivation of *Brucella* species.

Bacillus anthracis

Anthrax is an acute disease caused by *Bacillus anthracis*. The disease affects both humans and animals, and most forms of the disease are lethal. Infections occur when spores of *B. anthracis* enter the body via abrasion, inhalation, ingestion, and, on rare occasions, via insect vectors ([Reuter et al., 2011](#)). The endospores are extremely persistent in the environment and can remain viable in soils for up to 300 years ([Reuter et al., 2011](#)).

[Reuter et al. \(2011\)](#) conducted an experiment to speculate on the possible fate of *B. anthracis* within a field scale composting system. Because of regulatory requirements, safety considerations and the field scale design of the experiment, *B. anthracis* spores were not used, but rather spores of *B. licheniformis* and *B. thuringiensis* were chosen. The study showed that a one millionfold inactivation of *Bacillus* spores was achieved by exposure to compost and elevated temperatures over time. Variation in composting microclimates within the compost pile may explain why some spores remained viable in certain parts of the compost pile. A total inactivation of *Bacillus* spores was not possible. However, composting may still have merit as a means of bio-containment of infected carcasses and slaughterhouse wastes, reducing and diluting the transfer of infectious spores into the environment ([Reuter et al., 2011](#)).

[Bagge et al. \(2010\)](#) investigated the diversity of spore-forming bacteria in cattle manure, slaughterhouse waste and samples from biogas plants. Of particular interest in their study, were *Clostridium* and *Bacillus*. Before digested residues are reused for agriculture, biowaste must be adequately treated and proven to be hygienically safe ([Bagge et al., 2010](#)). To reduce the risk of spreading pathogens, pasteurization of biowaste at 70°C for an hour prior to AD is recommended. Pasteurization however will not inactivate bacterial spores ([Bagge et al., 2005](#); [Sahlström et al., 2008](#)). The results of [Bagge et al. \(2010\)](#) showed that *Bacillus* species seemed to pass the biogas process from biowaste to digested residues relatively unaffected. Due to their survival of pasteurization and the AD process, it is important to assess the risk of spreading digested residues from biogas plants containing *Bacillus* spores onto agricultural fields, and to take the necessary precautions.

The efficacy of AH for the inactivation of pure cultures of bacteria, including *B. subtilis*, for the disposal of infectious animal waste was evaluated in a study by [Kaye et al. \(1998\)](#). The tissue digester was operated at 110–120°C and approximately 103 kpa for 18 h. Samples were removed after a cooling phase at 50°C. The process was found to completely destroy *B. subtilis*. It can thus be expected that AH would be capable of the inactivation of the more deadly pathogen, *B. anthracis*.

Mycobacterium bovis (Beef tuberculosis)

Mycobacterium bovis is the causative agent of bovine tuberculosis, a chronic disease of cattle and other species. The disease can cause major losses in animal production and is a potentially debilitating zoonosis. *M. bovis* is capable of jumping the species barrier, and causing tuberculosis in humans, a disease normally caused by *M. tuberculosis*. Normally, *M. bovis* is transmitted to humans via infected milk, although it can also spread via aerosol droplets. However, actual infections in humans are rare, because of control measures put in place. Studies by [Croshaw et al. \(1971\)](#) showed that *M. bovis* was destroyed by the pasteurization of milk at 71.7°C for 15 sec, and at 62.8°C for 30 min.

Far more work has been conducted investigating the survival of *Mycobacterium avium subsp. paratuberculosis* after composting than *M. bovis*. *M. avium subsp. paratuberculosis* is a member of the same genus, and the causal agent of paratuberculosis, an intestinal infection of domestic and wild

ruminants. Grewel et al. (2006) showed that after 3 days of composting at 55°C, *M. avium subsp. paratuberculosis* were no longer detectable. Also, [Gobec et al. \(2009\)](#) showed that *M. avium subsp. paratuberculosis* was not able to be isolated 24 h after the start of composting. However, a report by [Haahes \(1996\)](#) indicated that farm yard (composted) manure must be exposed to a mean temperature of 60–70°C during the composting process for 3 weeks to destroy *M. bovis* bacilli. The authors concluded that as the majority of solid dung heaps do not reach this high a temperature, composted manure cannot necessarily be considered safe. These findings appear to be contradictory of the results of related *Mycobacterium* studies, and of the findings of pasteurization studies by [Croshaw et al. \(1971\)](#).

No studies investigating *M. bovis* in AD could be found upon intensive literature searches. In a mesophilic AD study by [Olsen et al. \(1985\)](#), *M. paratuberculosis* was detected and cultured up until 28 days of digestion. Under thermophilic conditions, however, *M. paratuberculosis* was inactivated after 24 h. In a study by [Slana et al. \(2011\)](#), viable *M. avium subsp. paratuberculosis* cells were detected using culture from fermenters up to 2 months. Therefore, the safety of the final products of digestion used for fertilization concerning the presence of *Mycobacterium* species cannot be certain.

[Kaye et al. \(1998\)](#) tested the survival of organisms after AH. All organisms tested, including *M. bovis* were completely destroyed by the AH process.

Erysipelothrix rhusiopathiae

Erysipelothrix rhusiopathiae is found all over the world and has been isolated from a variety of vertebrates as well as from soil. *E. rhusiopathiae* is primarily considered an animal pathogen, causing a disease known as erysipelas in turkeys, pigs, birds, sheep, fish, and reptiles ([Brooke and Riley, 1999](#)).

Erysipelothrix cultures are reportedly destroyed by exposure to moist heat at 55°C for 10 min ([Timoney et al., 1988](#)). A study conducted by Morrow et al. (1995) investigated composting as an approach to treat swine mortalities. The authors placed cultures of *E. rhusiopathiae* in compost piles. The temperatures reached in the composting process were high enough to destroy *E. rhusiopathiae*, and the authors concluded that properly produced composts did not pose a risk for transmitting disease.

[Olsen and Larsen \(1987\)](#) published the results of experiments investigating the reductions of pathogenic and indicator bacteria in animal slurry subjected to mesophilic (35°C) and thermophilic (53°C) AD. Under mesophilic AD conditions, a T90 value of 1.8 days was obtained for *E. rhusiopathiae*, while at 53°C, the T90 value was reduced to 1–2 h. A study conducted by [Han et al. \(2011\)](#) investigated the effects of an anaerobic lagoon fermentation and an autothermal thermophilic aerobic digestion on bacterial pathogens contained in raw swine manure. *E. rhusiopathiae* was present in the raw manure, however was no longer detectable following a mesophilic anaerobic lagoon fermentation. Manure treated by thermophilic aerobic digestion also did not yield detectable levels of *E. rhusiopathiae*. These findings suggest that AD processes would be successful in the inactivation of *E. rhusiopathiae*.

Although no literature reports regarding the survival of *E. rhusiopathiae* after a process of AH could be found, the report of [Kaye et al. \(1998\)](#) would indicate that AH should be capable of the inactivation of *E. rhusiopathiae*.

BSE

BSE, also known as mad cow disease, is a relatively new disease that primarily affects cattle. BSE can also cause a corresponding disease in humans—Creutzfeldt-Jakob disease ([Anon, 2003](#)). There is still much controversy regarding the causes of BSE and Creutzfeldt-Jakob disease, however the most common belief is that the infectious agents are prions, an abnormal form of a type of protein ([Anon, 2003](#)). However, the prion hypothesis has also been challenged and an autoimmune response theory has been postulated ([Ebringer et al., 1997](#)).

Currently, the public considers BSE to be the greatest concern to any bovine-based product. The risk, however, of spreading BSE via composting of catering wastes in the UK has been shown to be 'remote', because there are many controls in place for keeping the disease from entering the food system, and hence the food residuals stream in the UK today. In the slaughterhouse, TSE management aims to prevent infected material from entering the food and feed chains. According to EU legislation, animals suspected of TSE infection are separated and safely disposed of. Prions such as BSE are more resistant to heat than many viruses ([Gale et al., 2004](#)). In fact, BSE infected material remains infected after cooking, rendering and long periods of incubation in the soil ([Anon, 2003](#)). According to [Rohwer \(1984\)](#), less than a 0.5 log (70%) destruction of scrapie agent was seen after 60 min at 60°C and 80°C. It can therefore be assumed that a standard composting process whereby the temperature was maintained at 60°C for 2 days would not reduce BSE infectivity.

TSEs have also been reported to survive the operational temperatures at which AD are conducted ([Hinckley et al., 2008](#)). Studies by [Topper et al. \(2006\)](#) showed AD under both mesophilic and thermophilic conditions to be incapable of reducing or eliminating BSE. In a study conducted by [Brown et al. \(2000\)](#), infected brain material was heated to 600°C. Despite brains being totally ashed, when reconstituted with saline to their original weights, ashed brain material was able to transmit disease to 5 of 35 inoculated hamsters.

Apart from incineration (where temperatures of >850°C are reached; Gwyther et al 2011), AH is the only effective method known for the destruction of prion material ([NABC 2004](#)). A study carried out by the Institute of Animal Health at the University of Edinburgh, investigated the ability of AH to destroy BSE prions grown in the brains of mice. Infected mice heads were subjected to AH for either 3 or 6 h, and after neutralization of the hydrolysates, aliquots were injected into mice. Evidence of TSE was found in some mouse brains of mice injected with hydrolysate taken from the 3 h digestion, but significantly, no disease was found in the brains of mice injected with hydrolysate from the 6 h digestion ([NABC, 2004](#)). Studies conducted by [Murphy et al. \(2009\)](#) also showed scrapie to be inactivated by AH.

Aphtho virus

Foot-and-mouth disease (FMD) is an infectious and sometimes fatal viral disease caused by the Aphtho virus that affects domesticated and wild ruminants and pigs. Most infected animals eventually recover but often develop sequelae ([Guan et al., 2010](#)). The highly contagious nature of the virus and the severity of economic impacts associated with disease have resulted in FMD being labeled as the most important disease limiting the trade of animals and animal products throughout the world ([Arzt et al., 2011](#)).

The virus can survive for weeks or months in refrigerated internal organs, bone marrow, lymph and hemal nodes, glands, and residual blood, however can be inactivated within 3 days in skeletal muscle after slaughter due to reduced pH. The FMD virus can be inactivated using heat, however, the amount of virus inactivation is determined by the temperature ([Guan et al., 2010](#)), and by access of the heat to the virus infected material. Blackwell et al. (1988) reported that heating to an internal temperature of 58.3°C inactivated FMD in minced beef containing virus-infected lymph nodes, while temperatures of up to 79.4°C were required for minced meat in nylon tubes. The American Association of Food Hygiene Veterinarians (1990) reported that core temperatures of 93°C were needed to inactivate the FMD virus in heart muscle.

[Guan et al. \(2010\)](#) investigated the inactivation and degradation of FMD virus during composting of infected pig carcasses. FMD virus infected pig carcasses were composted in a mixture of chicken manure and wood shavings, and compost temperatures reached 50°C and 70°C by days 10 and 19,

respectively. Results indicated that the virus was inactivated in specimens in compost by day 10 and the viral RNA was degraded in skin and internal organ tissues by day 21.

Inactivation experiments conducted by [Turner et al. \(2000\)](#) in contrast, showed the FMD virus to be remarkably thermally stable, surviving with little or no loss of titre at 55°C and 60°C. Even at 65°C, the virus did not drop to below detectable levels within 5 min in a slurry. From these studies, the authors recommended treatment of slurry and water-containing FMD virus in full-scale mobile treatment plant operating at a minimum of 70°C.

As with other viruses, the bone marrow of infected animal carcasses can contain high loadings of FMD virus ([Farez and Morley, 1997](#)). Therefore, to effectively inactivate FMD virus from animal waste material, a composting process where the temperature was maintained at greater than 65°C for at least 2 days would need to be used. According to [Gale et al. \(2004\)](#), a composting temperature of 60°C for 2 days would give at least a 6-log reduction of all exotic pig viruses, including FMD, even in the bone marrow of whole pig carcasses discarded for composting.

No information could be found regarding the survival of FMD virus after either mesophilic or thermophilic AD. Considering the heat stability of the virus, it could be predicted that AD would not successfully inactivate FMD virus. However, the combination of a pasteurization step and an AD process could be expected to be successful in the inactivation of the virus.

No literature reports regarding the survival of FMD virus after a process of AH could be found. As the report of [Kaye et al. \(1998\)](#) states that the process was found to completely destroy all representative classes of potentially infectious agents, it can be expected that AH would be capable of the inactivation of this virus.

Lyssa virus (Rabies)

Rabies is a disease caused by the lyssa virus, and is an acute encephalitis in warm-blooded animals ([Kopcha et al., 2010](#)). In humans, rabies is almost always fatal if post-exposure prophylaxis is not administered prior to the onset of severe symptoms. The economic impact of the disease is significant, with the virus causing death of livestock in some countries.

The rabies virus is able to be inactivated by heat ([Kopcha et al., 2010](#)) and thus a pasteurization step at 70°C should be considered successful in rabies inactivation. No information was able to be found on composting inactivation of the virus, but based on the findings of [Kopcha et al. \(2010\)](#), it would be likely that composting would also successfully inactivate the virus. Studies by [Kissling and Reese \(1963\)](#) investigated virus stability at different temperatures. Rabies tissue culture-adapted virus in serum-free medium was reported to be sensitive to heat inactivation. At 56°C, almost all virus was inactivated within 30 min, while at 37°C, more than 99 % of the virus was inactivated within 24 h. At 37°C, no virus was viable after 32–48 h.

No information could be found upon extensive literature searching on the survival of the rabies virus after an AD process. Considering the heat sensitivity of the virus, it is likely that it would be inactivated after a thermophilic AD, but it is not certain whether a mesophilic AD process would have the same effect. When combined with a pasteurization step however, one could hypothesize that the virus would be inactivated.

Again, no literature reports regarding the survival of the rabies virus after a process of AH could be found. Based on the findings of [Kaye et al. \(1998\)](#), it would however be expected that inactivation of the virus would result from AH.

African swine fever virus

African swine fever (ASF) is a viral disease (genus *Asfivirus*) which causes a devastating haemorrhagic fever of pigs with mortality rates approaching 100% ([Costard et al., 2009](#)). Virus is excreted in the faeces of infected pigs, and as faeces mostly are transferred to a slurry store prior to the infection being identified, viral contamination of large quantities of pig slurry can occur inadvertently.

ASF virus has been reported to be quite resistant to inactivation, and can survive many freeze-thaw cycles ([Turner et al., 1998](#)). It is also resistant to changes in pH, and certain strains are resistant to complete inactivation at pH values between 4 and 13 ([Turner et al., 1998](#)). The virus is however very sensitive to drying, and can be inactivated by lipid solvents because of its lipid envelope ([Turner et al., 1998](#)).

ASF virus is however heat sensitive. In studies conducted by [Plowright and Parker \(1967\)](#), ASF virus was shown to be inactivated (5 log inactivation) by 90 min at 56°C. However, work done by [Turner et al. \(1998\)](#) indicated the virus to be inactivated at 50°C in 30 min, at 56°C within 90 sec and within seconds at 60°C.

The findings of [Turner et al. \(1998\)](#) described above, as well as projected costs of treatment for virus inactivation resulted in the authors deciding that heat was the most effective means of ASF virus inactivation. This is because heat treatment was found to be very rapid and consistent at a temperature of 56°C, while alkali inactivation was slower. Also, heat can be recovered, thus reducing costs. These authors designed a pilot scale treatment plant to treat pig slurry at a minimum temperature of 65°C, and maintained this temperature in at least 99.99% of the material for a minimum of 5 min. This was done so to provide a reasonable safety margin for virus inactivation.

The bone marrow of infected pig carcasses contains high loadings of ASF virus ([Gale et al., 2004](#)). When considering the composting of an animal carcass, the times and temperature of the process must be carefully considered. It has been estimated that a sphere of diameter 40 cm (which would be similar to a large leg or carcass of pork containing the bone) would require 40 h to reach a temperature of 56°C at the centre when the surrounding composting temperature is 60°C ([Haug, 1993](#)). Therefore, a composting process with a temperature of 60°C maintained for 2 days would give at least a 6-log reduction of all exotic pig viruses, including ASF virus, even in the bone marrow of whole pig carcasses ([Gale et al., 2004](#)). As studies have shown ASF virus to be inactivated within seconds at 60°C, it would appear that a correctly performed composting process should be successful in inactivating ASF virus.

No information could be found regarding AD and the survival rates of ASF virus subjected to the process. While no predictions can be made as to the survival of the virus in a mesophilic process, it could be predicted that a thermophilic process may successfully inactivate the virus.

A 1% solution of both NaOH or Ca(OH)₂ was found to be able to result in a 4 fold inactivation of the virus at 4°C within 150 sec. More dilute solutions (0.5%) of both chemicals were however not found to be able to inactivate virus at 22°C in 5 min ([Turner et al., 1998](#)). It could be expected that a AH process, which uses alkaline solution as well as heat to inactivate microbial organisms would be successful in the inactivation of ASF virus.

Phlebo virus (Rift Valley fever)

Rift Valley fever (RVF) is a viral zoonosis resulting in fever. The disease is caused by the RVF virus, a member of the *Phlebovirus* genus. It is spread by the bite of infected mosquitoes, or by exposure to tissues or blood of infected animals ([Zaki et al., 2006](#)). Humans infected with the virus have self-limited febrile illness, but retinal degeneration (5–10%), haemorrhagic fever (<1%), or encephalitis (<1%) can also develop ([Laughlin et al., 1979](#); [Meegan and Bailey, 1989](#)). The RVF virus is susceptible to low pH (≤ 6.2), lipid solvents and detergents, as well as solutions of sodium or calcium hypochlorite

with residual chlorine content greater than 5000 ppm. In a neutral or alkaline pH, mixed with serum or other proteins, the virus can survive for as long as four months at 4°C and eight years below 0°C. The virus is also quickly destroyed by pH changes in decomposing carcasses (http://www.cfsph.iastate.edu/Factsheets/pdfs/rift_valley_fever.pdf). Thus, although no literature can be found on AH of animals infected with RVF virus, it would appear that AH would not be a recommended method of treatment of animal carcasses in order to inactivate the virus.

Unfortunately, no information could be found on composting or AD with respect to the inactivation of RVF virus, although [Flory et al. \(2010\)](#) report that composting approaches can be used to treat RVF diseased animals, thus preventing disease outbreaks.

Cysticercus bovis (beef measles)

Bovine cysticercosis is a zoonotic disease found worldwide affecting the muscles of cattle ([Pawlowski and Schultz, 1972](#); [Ogunremi and Benjamin, 2010](#)). The disease is most prevalent in countries where poor sanitation practices on cattle farms are common and where cultural habits include eating undercooked meat. It does not represent a serious human health risk. Bovine cysticercosis is caused by *Cysticercus bovis*, the larval stage of *Taenia saginata*, a species of human tapeworm ([McFadden et al., 2011](#)). Humans can acquire intestinal tapeworm infections by the consumption of beef containing the parasite. Disease in cattle is initiated by the ingestion of materials contaminated with tapeworm eggs originating from human feces larvae of a human tapeworm. Cattle become infected with bovine cysticercosis by ingesting materials contaminated with tapeworm eggs originating from human faeces ([McFadden et al., 2011](#)).

A study was conducted by [Hughes et al. \(2005\)](#) to investigate the survival of *T. saginata* ova after AD at 35°C for 10 days followed by lagooning for 15 days. Results indicated that viability and infectivity were completely destroyed. The authors also showed that a 3 h treatment at 55°C in crude sludge resulted in a 99 % reduction of ova infectivity. It could thus be assumed that a 70°C pasteurization step prior to AD treatment, as is the regulation in Europe, would successfully inactivate bovine cysticercosis.

Another study by [Morris et al. \(1986\)](#) showed 100% efficacy of sanitation of *T. saginata* at 35°C. A thorough review of the literature has failed to find studies whereby the inactivation of *T. saginata* by composting was investigated. However, the US Environmental Protection Agency (Part 503) sets standards for the destruction and concentration of pathogens in composted biosolids. These standards are commonly used as marketplace specifications for compost sold for public use. By maintaining these standards, various harmful pathogens should be destroyed (<http://ccpeat.com/literature/composttech.pdf>). According to the standards, *T. saginata* does not survive for more than a few minutes at 55°C. Thus, a standard composting procedure would successfully inactivate this organism.

No information could be obtained regarding the inactivation efficiency of AH on *T. saginata*. However, [Kaye et al. \(1998\)](#) showed *Giardia* cysts to be completely destroyed by AH, an indication that slaughterhouse waste material infected by bovine cysticercosis might also successfully be treated by AH.

Conclusions

In the past, solid slaughterhouse wastes were most commonly treated by rendering, the process providing slaughterhouses with an additional source of income. However, because of the risk of TSEs, the economic value of such products has been reduced significantly, and in fact, such products must in many cases be treated as waste themselves ([Palatsi et al., 2011](#)). The cost for the safe disposal of

slaughterhouse waste in recent years has thus considerably increased. This is primarily due to health risks from the presence of pathogens in such wastes. Several different possibilities for their disposal exist, as described in this review.

Composting is one alternative for the disposal of slaughterhouse wastes. The process has various benefits, including reduced environmental pollution, the generation of a valuable byproduct, and the destruction of a majority of pathogens ([NABC, 2004](#)). The successful conversion of such wastes into good-quality compost however requires close control. When performed under stringent management, the final product should not pose a risk to animal and human health ([Gale, 2004](#)). There are however some pathogens that are not able to be destroyed by composting, such as prions and spore forming bacteria.

The process of AH of slaughterhouse wastes is relatively new. It uses a strong base, heat and temperature to catalyze the hydrolysis of biological materials into a sterile aqueous solution consisting of peptides, amino acids, sugars and soaps ([Kaye et al., 1998](#)). This effluent is highly alkaline and very rich in nutrients, and although it can be released into a sanitary sewer, it can also potentially pose problems ([NABC, 2004](#)). It has been found to be extremely effective in the elimination of many pathogens and prions from carcasses as well as from animal wastes. The waste from the process is however very rich in nutrients, and would thus offer high biogas generation potential.

AD is today one of the most promising methods for the disposal of slaughterhouse waste ([Gwyther et al., 2011](#)). This process not only produces a digestate which can be used as a valuable fertilizer, but it also produces heat and biogas, that in turn can be converted to energy. Moreover, slaughterhouse wastes are rich in proteins and nitrogen, and thus are ideal substrates for the AD process. Numerous studies have reported various levels of effectiveness in the removal of different pathogens using AD.

The results of our extensive literature review concerning the survival of pathogens after composting, AH and AD are summarized in [Table 1](#). Although there would not appear to be a single approach that would inactivate all the pathogens investigated in this study, an AD process with either a pre- or post-pasteurization step would most likely inactivate the majority of microorganisms. Prions would however survive a pasteurization and an AD process, as would spore-forming bacteria. The survival of prions should however not be a cause for concern, as any biogas plant operator should be able to prevent diseased animals or suspected TSE diseased animals from entering the process.

Table 1.

Summary of inactivation of different pathogens by different treatments.

Pathogen	Inactivation by					
	Pasteurization [*] (70°C)	Mesophilic AD (37°C)	Thermophilic AD (55°C)	Pre- asteurization and anaerobic digestion at 37°C ^{**}	Composting	Alkaline hydrolysis
<i>Escherichia coli</i>	++	+	+	(PI)	+	(PI)
<i>Salmonella</i>	++	+	++	(PI)	++	(PI)
<i>Clostridium</i>	-	-	-	(-)	-	(PI)
<i>Brucella abortus</i>	++	NI	(PI)	(PI)	NI	(PI)
<i>Bacillus anthracis</i>	-	-	-	(-)	-	(PI)
<i>Mycobacterium bovis</i>	++	(+)	(PI)	(PI)	C	++
<i>Erysipelothrix rhusiopathiae</i>	++	+	++	(PI)	++	(PI)
BSE prion	-	-	-	(-)	-	++
Aphtho virus	(PI)	NI	(+)	(PI)	C	(PI)
Rabies virus	++	NI	(PI)	(PI)	(PI)	(PI)
African Swine Fever Virus	++	NI	(PI)	(PI)	++	(PI)
Phlebo virus	(PI)	NI	NI	(PI)	(PI)	-
<i>Cysticercus bovis</i>	(PI)	++	++	(PI)	(PI)	(PI)

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++, total inactivation; +, inactivation; -, survival; (PI), no information on process, but predicted inactivation of pathogen; (-), no information found, but predicted survival of pathogen; NI, no information found; C, contradictory information; *, Pasteurization for 60 min; **, Pre-pasteurization for 60 min at 70°C.

Although spore-formers will also not be removed from the joint processes of AD and pasteurization, the numbers could be expected to be significantly reduced. The European Union has laid down various laws concerning the disposal of animal byproducts, including ABP-Regulation (Regulation (EC) no. 1774/2002), which defines new treatment possibilities and corresponding mandatory processing

parameters. In Sweden, slaughterhouse wastes are treated with a 70°C pasteurization step prior to AD, and digestates are used in agriculture. No problems seem to have arisen with spore-forming pathogens such as *Clostridium* and *Bacillus* as a result of such treatment. The benefits of using AD to treat slaughterhouse wastes are immense, and not only are the unpleasant waste products of the ever-growing meat industry disposed of, but renewable energy is produced. Alternatively, an AH process, combined with AD should result in the most efficient method possible for the elimination of pathogens, and at the same time, produce energy. This would however require some research to be conducted to investigate the best way to do this, to prevent any inhibitions and problems occurring from using the alkaline waste in the AD process.

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TECH

USDA punishes slaughterhouse accused of abuses

James Bruggers @jbruggers

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Story Highlights

Animal welfare group had been urging USDA to shut down a Bracken County slaughterhouse.

USDA has pulled its inspectors from the business on an indefinite basis.

Owner calls it a misunderstanding typical of city people..

Federal regulators have indefinitely removed their inspectors from a mom-and-pop slaughterhouse in Northern Kentucky cited for repeated violations of failing to quickly and humanely kill cattle and pigs for market.

Without inspectors, Brooksville Meat and Fabrication Center in Bracken County cannot get a USDA stamp of approval on meat processed for commercial sale. That limits the ability of the meat to be sold.

An animal welfare group that has been pressuring the government to shut down the company called the U.S. Department of Agriculture enforcement action unprecedented.

“We don’t think this has ever happened before, based purely on humane concerns,” as opposed to food safety concerns, said Bruce G. Friedrich, senior policy director with New York-based Farm Sanctuary, which operates sanctuaries for rescued farm animals.

Paul Shapiro, a spokesman for the Humane Society of the United States, called the enforcement action “extremely rare and signifies an event that is very important.”

MORE | Watchdog Earth coverage of troubled slaughterhouse

The USDA would not confirm whether it had taken similar actions on similar facilities. But the agency said in an email that an administrative law judge on March 25 upheld an order

that indefinitely removed inspectors from the business, after four temporary suspensions in 2013.

Keith Wright, the company's owner defended his methods.

"It's just a confusing thing that people in the city don't understand," Wright said. "Some animals don't go down the first time you shoot them."

Wright, who said he's been without the inspectors for several months, said he's a victim of a toughening of the enforcement of the Humane Slaughter Act.

He said his operation had been slaughtering about 50 or 60 cattle or swine a year.

The Courier-Journal first reported in November that the Agriculture Department had cited the company for allegedly violating regulations under the Humane Slaughter Act, which says livestock needs to be rendered "insensible" to pain before being slaughtered. In some cases, workers who were dispatching livestock with a .22-caliber gun were taking multiple shots and several minutes to kill the animals, with an inspector describing such actions as "egregious" violations, the newspaper reported.

Farm Sanctuary teamed with the Animal Law Clinic at the Northwestern School of Law at Lewis & Clark College in Portland, Ore., to scrutinize the agency's operations.

"One of our goals in writing to USDA was to encourage them to pull the plant's grant of federal inspection, which is the pinnacle of the agency's administrative remedies, and which it has never done purely for humane concerns, we don't believe," Friedrich said.

The statement provided by USDA said Wright still holds a Grant of Inspection for the establishment but that the business is "indefinitely suspended until the owner can provide adequate assurances that all slaughter and handling of livestock shall be conducted humanely."

Wright said he is working to satisfy the USDA so he can do commercial slaughtering again.

But Friedrich said his group is urging the federal government to file criminal charges.

Reach reporter James Bruggers at (502) 582-4645 or on Twitter @jbruggers.



Critics worry about food safety as federal meat inspectors face work overload, burnout

By Brett Bachman and Samantha Stokes/For The Midwest Center for Investigative Reporting September 18, 2019

OMAHA, Neb. — At eight months pregnant, government food inspector Rosalie Arriaga was scheduled in March 2018 to handle twice her normal workload at the meat processing plants she was assigned to cover.

It was her third straight week of double coverage, according to agency schedules given to the Midwest Center for Investigative Reporting.

A few weeks earlier, one of Arriaga's coworkers had sent a concerned email to their supervisor: "Are they trying to make something happen to Rosalie carrying her child the last couple of weeks!!" the coworker asked.

Arriaga, a consumer safety inspector at the United States Department of Agriculture's Food Safety and Inspection Service, had been put in charge of food safety at six corporate slaughterhouses around Omaha.

When Arriaga finally called in sick that Friday, there was no one available to replace her.

During that shift, those meat-packing plants went hours without someone overseeing the complicated logistics of food safety.

Arriaga declined to comment for this story, though she confirmed the account. And her story of scrambling to complete too much work in too little time is not uncommon.

Inspectors say that due to long-standing problems that have gotten worse in recent years, adequate oversight of meat processing has become all but impossible.

The Food Safety and Inspection Service's mission is "protecting the public's health by ensuring the safety of meat, poultry, and processed egg products," according to its website. Though without proper inspection inside these plants, food safety experts say the risk of foodborne illness for millions of Americans increases sharply.

Each plant has a veterinarian who inspects animals prior to slaughter, and at least two types of inspectors inside each facility: The first are slaughter line inspectors who examine each carcass to make sure the meat is safe for consumption, and who are mandated to be present in order for a plant to operate.

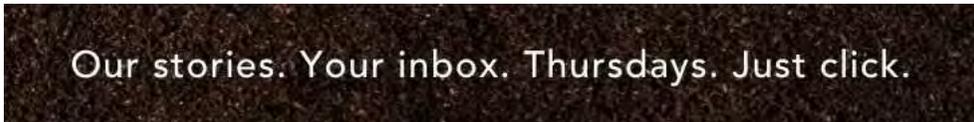
The second are consumer safety inspectors, who oversee a plant's food safety plans and perform sanitation checks at multiple facilities during any given shift.

Consumer safety inspectors also routinely take over slaughter line inspections in order to give those employees breaks or to fill in for short-term staffing shortages, such as an employee calling in sick or quitting unexpectedly — a job duty that many of these federal employees say has become more common in recent years due to vacancies in those positions.

Short staffing and burn out

A nine-month investigation by the Midwest Center for Investigative Reporting found dozens of similar situations at the USDA's Food Safety and Inspection Service, with routine vacancies that leave the remaining federal food inspectors vulnerable to burnout, work overload and other job hazards.

In several cases, employees in other roles are oftentimes forced to abandon their own job duties to cover the slaughter line inspections mandated for plants to operate.



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USDA representatives reiterated during a phone interview that every carcass on the line is inspected without fail — if they weren't, private slaughterhouses could not operate.

Administrators on the call disputed that the public has seen any increase in risk due to other employees filling in for vacancies on the slaughter line and said staffing for all positions is adequate.

Officials did acknowledge their recent work to hire more meat inspectors, including a recent move to reclassify a number of positions to make them more attractive for entry level applicants.

“I cannot speak to any anecdotes,” Food Safety and Inspection Service Administrator Carmen Rottenberg said. “But I can say that we work really hard to keep our vacancy rates low.”

Agency representatives also suggested that criticism of the meat inspection system was generated by unions and pro-union lobbyists, while dismissing incidents of insufficient inspection as isolated incidents that do not properly represent the agency’s successful effort to keep America’s food supply safe.



U.S. Department of Agriculture (USDA) meat inspectors and graders perform their mission. USDA photo by Preston Keres

But a review of internal documents, hundreds of pages of public records and interviews with more than a dozen current and former food inspectors, as well as more than 30 food safety experts and industry representatives, reveal the extent to which key agency duties are going unfulfilled.

- As of March 2019, in some districts, up to one in every seven federally funded meat and poultry inspection positions were sitting vacant — a total of nearly 700 nationwide.
- The shortage has created situations in which some inspectors are forced to cover double and triple the number of meat processing plants for which they would be normally scheduled.
- In some cases, facilities go entire shifts without supervision from consumer safety inspectors, who enforce important sanitation policies, oversee facilities’ food safety plans and the production of processed meat products.
- Internal emails show that leadership at the agency sometimes notifies plants of the gaps in inspection by consumer safety inspectors, which both agency employees and experts say gives companies increased opportunity to avoid food safety rules.

- Multiple consumer safety inspectors said their superiors asked them to seek permission each time they marked down a task as incomplete in the agency’s internal tracking system, creating a “chilling effect” and encouraging the underreporting of incomplete assignments.

Such a task might be inspecting the facility for mold, or improperly stored chemicals, or even checking that a plant is following the proper allergen labeling rules.

The Food Safety and Inspection Service currently manages about 7,800 total inspector positions. This roughly mirrors the agency’s staffing levels in 1980, although the amount of meat and poultry consumed in the country has increased dramatically during the same period, from 193.7 pounds per person in 1980 to a record 219.5 pounds in 2018, according to USDA data.



Agriculture Secretary Sonny Perdue visits Triumph Foods pork processing facility April 28, 2017. The facility houses 2,800 employees in St. Joseph, Mo. USDA photo by Preston Keres

Despite the agency’s stagnant number of jobs, it’s had trouble in recent years even filling the positions that already exist. According to agency data obtained via Freedom of Information Act request, the total vacancy rate for all Food Safety and Inspection Service inspector positions in March was 8.75 percent.

The situation is especially bad in the Midwestern districts encompassing parts of Iowa, Missouri, Nebraska and Colorado, which supply most of the country’s meat. As of this March, more than 17 percent of all slaughter line inspection positions in the Denver and Des Moines Districts were vacant.

And when there are too few slaughter line inspectors working in a plant, consumer safety inspectors working in those districts say they must also shoulder the line-inspection duties, thus failing to complete more of their own tasks.

“We don’t believe we are short-staffed,” Rottenberg said.

She also noted the agency looks at staffing more holistically: public health veterinarians, relief inspectors and “other resources” provide the agency with the manpower to fill

any vacant positions, and accomplish its mandate: a safe supply of meat and poultry for American consumers.

“We’re always going to have the resources to ensure we are inspecting every single carcass that goes through a slaughter facility,” said Dr. Philip Bronstein, assistant administrator for the Food Safety and Inspection Service’s department of field operations.

Although Food Safety and Inspection Service leadership agreed to a phone interview, representatives declined to respond to a written list of questions.

Eighteen plants in one day

Just a few weeks after Arriaga called in sick, another consumer safety inspector in the same Nebraska circuit was scheduled for five straight days of 16.5-hour shifts.

Schedules from June 2019 show yet another consumer safety inspector in Jacksonville, Florida, was slated to visit 18 plants in one day. It’s a job that his coworkers said would require between five and six hours of driving, even with favorable traffic. Forgoing bathroom breaks or time to eat, an inspector in the same circuit said that would still only leave roughly six minutes in each facility — not nearly enough to perform a proper inspection, which multiple agency employees said should take at least an hour or more.

Employees at the Food Safety and Inspection Service have a name for the hours spent driving hundreds of miles between work sites only to walk inside and almost immediately walk back out: “windshield duty.” And those are the best days, when there are enough employees to staff every plant.



Tyson Processing Services in Omaha, Nebraska. July 20, 2019. Photo by John Peterson for the Midwest Center for Investigative Reporting

“I can say with certainty these are not isolated incidents,” said Stan Painter, a 30-plus-year veteran of the agency and a chairman of the American Federation of Government Employees’ food safety inspectors’ union.

“It’s only a matter of time before there’s a big outbreak of something, and I’m of the opinion that the consumer is already being affected,” said Painter. “The agency has ostrich syndrome. Everyone’s head is in the sand.”

Rottenberg dismissed these instances as “anecdotes” and said the agency has been working hard in recent months to keep vacancy rates for field inspectors low.

After the Midwest Center began reporting this story, the Food Safety and Inspection Service announced the plan in August 2019 to reclassify a number of its consumer safety inspector positions down one level — lowering employment qualification standards and potentially reducing pay for some employees in the process.

The goal is to “improve flexibility in addressing staffing challenges” and “make the CSI position more attractive to recent college graduates who may seek to work for FSIS immediately upon graduation,” according to an email about the changes sent by the agency to congressional staff at the House Agriculture Appropriations Subcommittee.

Representatives from the USDA also said the United States’ supply of meat and poultry is the safest in the world — largely due to the agency’s mandate to visually inspect every animal slaughtered in every facility.

“Every carcass is inspected - 100 percent,” said USDA Program Analyst Roxanne Lane. “No slaughterhouse can operate without us being there. We are there, we have to be there, and we are.”



Agriculture Secretary Sonny Perdue visits Triumph Foods pork processing facility April 28, 2017. The facility houses 2,800 employees in St. Joseph, Mo. USDA photo by Preston Keres

Key roles of safety inspectors

Consumer safety inspectors are not required to be in every plant 100 percent of the time, according to agency policy, but each facility must be visited by a consumer safety inspector at least once per shift - typically between eight and 12 hours. It’s a mandate employees say has become increasingly difficult to accomplish.

Indeed, Tyson Foods filed a \$2.4 million lawsuit against the USDA in May over insufficient inspections, alleging an agency employee lied about checking thousands of hogs for contamination and illness at the company’s plant in Storm Lake, Iowa. The company said it was forced to throw out more than 8,000 hog carcasses as a precaution, according to court documents filed in the Northern District of Iowa.

In the suit, Tyson alleges video footage from the facility shows USDA veterinary medical scientist Yolanda Thomson signing inspection cards from the front seat of her car without ever entering the facility, in what would be a clear falsification of the documents.

But Thompson's normal assignment was a nearby turkey plant, and she was working the extra shift because the USDA's Des Moines district is continuously short-staffed, according to Paula Schelling, a food safety inspector's union representative.

Multiple district employees said they had also been pushed well into overtime, including one consumer safety inspector who shared 2018 paystubs with the Midwest center showing at least four instances of consecutive work weeks of more than 70 hours each.

In August, Tyson and the USDA had begun working towards a settlement, according to court filings. Tyson and its legal counsel did not respond to requests for comment on the lawsuit.

"We have consumer safety inspectors pulled out of assignments and double or triple staffed to cover all the vacancies in the country. These inspectors can only do so much," Eric Rothell, an 18-year veteran of the agency and president of his union's local in Nebraska, wrote in a letter to USDA leadership last year.



Eric Rothell poses in front of a meat processing plant in Omaha, NE on July 20, 2019. Photo by John Peterson for the Midwest Center for Investigative Reporting

Since then, he said the agency has shrugged off his repeated attempts to bring these problems to light.

"Establishments continue to produce products that are bought and consumed by Americans with the USDA seal when, in reality, little to no inspection has occurred at all," Rothell wrote. "I don't feel like I'm crying wolf here. I've been in this agency for a long time, seen the best of the best and the worst of the worst. How we are protecting the consumer right now is lacking."

A January 2019 report from the Public Interest Research Group, a non-partisan federation of nonprofit organizations in the United States and Canada, found that since 2013 the most dangerous kind of meat and poultry recalls — Class 1 — have increased by more than 80

percent. This accounts for the vast majority of the 10 percent increase in total food recalls over that same period, according to USDA data.

Some of this jump can be attributed to a more conservative system of recalls, including new rules surrounding allergen labeling that a USDA spokesperson pointed to as a major contributor to the increase. But, as the report notes, “there is still a clear trend of more meat and poultry being recalled due to contamination.”

The report’s author, Adam Garber, as well as other food safety experts say inadequate inspections by the USDA also likely deserve some of the blame.

“Either there’s always been a problem and we’re just discovering it now, or things are getting worse,” said Garber. “That’s a bad thing for the consumer either way.”

Longstanding problems

In a 1991 Pulitzer Prize-winning investigation into issues within the USDA, the Kansas City Star found the Food Safety and Inspection Service was “poorly supervised, inadequately trained and plagued by work-related injuries.”

Steve Cockerham, a source for the Star’s reporters and a USDA food inspector at the time, appeared in front of a National Academy of Sciences committee that year to testify on the deteriorating state of meat safety. He brought with him a plastic bag of packaged beef, riddled with shotgun pellets: “100 percent USDA-approved buckshot,” he said.

Today, he’s the manager of a hardware store in Grand Island, Nebraska. He resigned from the agency in 2015.

“It absolutely got worse,” Cockerham said of the agency’s staffing problems prior to his departure. “I left it in the rearview mirror. I just had to get out of there and get a new life.”



Tyson Processing Services in Omaha, Nebraska. July 20, 2019. Photo by John Peterson for the Midwest Center for Investigative Reporting

In response to a Midwest Center inquiry for current vacancy rates, the Food Safety and Inspection Service said the agency had improved its staffing numbers and as of July 2019 was operating with a 6.89 percent vacancy rate for all “in-plant” positions, which includes line inspectors, consumer safety inspectors, public health veterinarians and other agency employees.

Additionally, the agency said the July vacancy rate for all consumer safety inspector positions sat at 5.57 percent. The Food Safety and Inspection Service declined to provide the raw data used to calculate current vacancy rate totals.

The government shutdown earlier this year didn't help the situation, said Tony Corbo, a senior lobbyist at consumer watchdog nonprofit Food and Water Watch.

Corbo has studied the agency full-time for almost 20 years and consults with both sides of the aisle in Congress on regulatory issues involving agriculture and food production.

For their part, USDA representatives argued that Corbo is not purely a consumer advocate because of his involvement in negotiations between the inspectors' union and the USDA over several agency programs — a contention Corbo denies.

Staffing reports obtained by Food and Water Watch show that 75 inspectors — who, as essential employees, were not subject to furlough but were also not being paid — quit during the month-long shutdown. Although that number only constitutes about one percent of the agency's total workforce, it is one more contributor to staff shortages.

Corbo has been filing Freedom of Information Act Requests for the agency's monthly staffing numbers for more than a decade, and says the current situation constitutes a "crisis."

"Work is not being done in these plants, period," he said. "Something is clearly out of whack."

No Coverage

On the day Rosalie Arriaga called in sick, leaving six plants without coverage for 39 combined hours, a district supervisor wrote to another consumer safety inspector: "Please give all plants my info. Also let them know there will be no coverage after you are gone."

"There will be no coverage past your coverage," the same supervisor wrote to several other inspectors on the same day. "I will be available for emergencies."

Announcing there will be no consumer safety inspector visiting a plant on a given day creates an opening for companies to skirt food safety rules, several inspectors said.

The USDA Inspector General's office acknowledged as much in [a 2012 audit of the Food Safety and Inspection Service](https://www.usda.gov/oig/webdocs/24601-0011-HY.pdf) (<https://www.usda.gov/oig/webdocs/24601-0011-HY.pdf>), writing about inspectors who physically cannot make it to every plant on their schedule: "the lack of mitigating procedures increases the risk that unsafe meat and poultry products will reach the public."

The audit was originally intended to "evaluate the impact of inspection personnel shortages on the agency's ability to accomplish its mission of protecting consumers," but the inspector general ultimately said it could not make a determination due to a lack of data.

In its response to the report, the agency said that when inspectors missed certain tasks, the person working the next day would look over company records to ensure safety rules were followed.



U.S. Department of Agriculture (USDA) meat inspectors and graders perform their mission. USDA photo by Preston Keres

But inspectors who spoke with the Midwest Center said little has been done to prevent the underlying problem of overscheduling and hours-long production shifts without a consumer safety inspector scheduled to work in the first place.

“I haven’t been able to do my job for some time due to understaffing and having to fill in for line inspectors,” said another consumer safety inspector who requested anonymity to preserve his employment at the USDA.

“It’s getting worse,” he said. “I don’t remember it ever being this bad.”

In addition, several current consumer safety inspectors cited pushback from their supervisors when trying to document incomplete assignments as reason to be skeptical of the official USDA data being used to measure their effectiveness.

Agency emails given to the Midwest Center from January show a supervisor in the Memphis circuit emailing an inspector to ask that the employee gain official approval from upper management before recording missed tasks.

“Failure to meet this goal will be reflected and documented,” the supervisor wrote in the email. “Dereliction of duties is unacceptable.”

Multiple inspectors said they encountered similar in-person requests from supervisors that weren’t recorded through email. They worry that this practice, which is not official agency policy, creates an unnecessary extra step that could make data less reliable.

“It has a real chilling effect,” Painter said.

And as food recalls continue, the agency’s former Chief Public Health Veterinarian, Dr. Pat Basu, worries the increased chances of a major outbreak may soon become a reality.

“If we continue to wait to act, by then it will be too late,” he said. “[The people in charge] don’t have the qualifications to understand the danger of the situation.”

Inspectors say they feel like an afterthought, asked to work long hours under immense pressure to protect their fellow consumers from foodborne illness and death.

“Why is it so hard for management to just listen to the field inspectors?” Rothell said. “Does it actually take someone becoming ill or dying before we quit making excuses and staff the vacancies?”

Please note: The story was updated on September 19, 2019, to reflect that meat inspectors were considered “essential” employees during the federal shutdown earlier this year. An earlier version incorrectly noted they were “non-essential” employees.

This story was also later updated to correct the name of the Public Interest Research Group. An earlier version incorrectly stated the name as the Public Information Research Group.

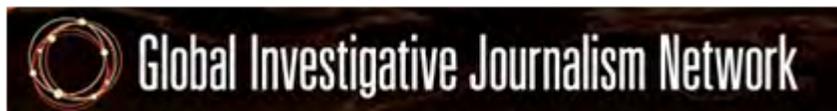
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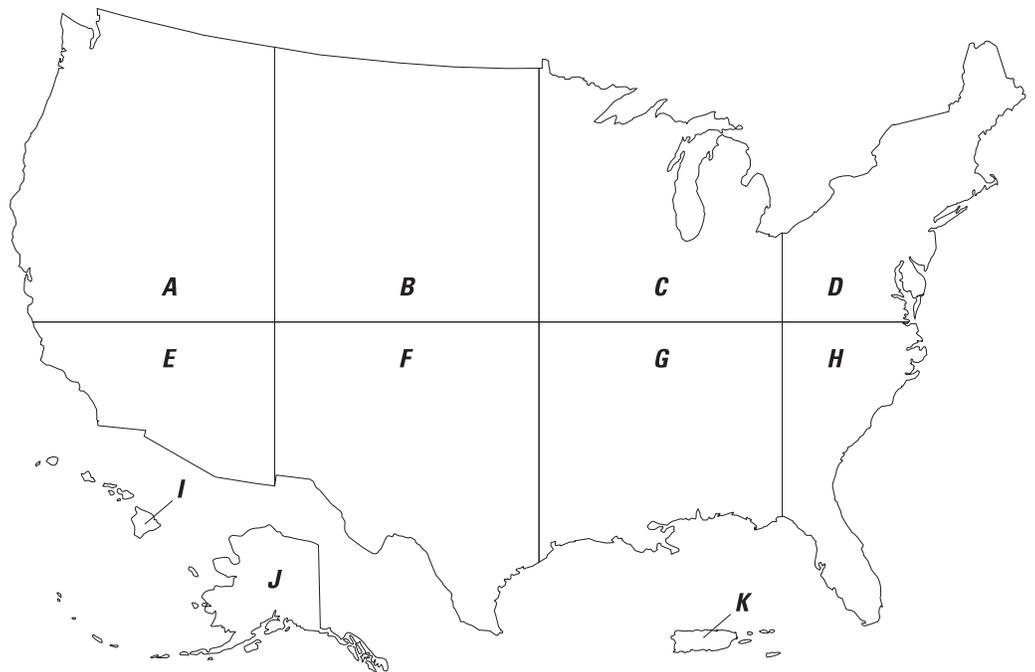
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