International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
DOI: 10.22192/ijarbs Coden: IJARQG (USA) Volume 7, Issue 12 -2020

Review Article

DOI: http://dx.doi.org/10.22192/ijarbs.2020.07.12.018

Swine and poultry carcasses disposal methods in major epizootics in Nigeria: available and alternative methods.

*[1]Abonyi, F. O., [2]Machebe, N. S. and [3]Gary A. Flory

[1]Department of Animal Health and Production, University of Nigeria, Nsukka, Nigeria
[2]Department of Animal Science, Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria
[3]Virginia Department of Environmental Quality, P.P. Box 3000, Harrisonburg, VA
*Corresponding author: Abonyi, F. O., E-mail: *festus.abonyi@unn.edu.ng*

Abstract

Animal disease-related disasters such as African Swine Fever (ASF) and Highly Pathogenic Avian Influenza (HPAI) outbreaks in Nigeria in 1997 and 2006 generated large number of dead swine and poultry carcasses. Concentration of intensive animal production, bioterrorism and natural disasters may also lead to death of animals in large numbers. Widespread livestock deaths create logistic problems of carcass disposal that if not handled quickly and effectively can lead to major food security problems or gross economic losses. Difficulties encountered by farm owners and disaster management officials during such events make the need for establishment of efficient and effective advance planning in any country inevitable. However, before any problem can be solved, it must first be identified. In Nigeria, many livestock owners dispose animal carcasses through unacceptable manners due to lack of awareness on its implications, existence of regulatory control on this and other alternative disposal methods. This paper therefore highlighted carcass disposal methods during two major ASF and HPAI outbreaks in Nigeria. An overview of current internationally accepted carcass disposal techniques was provided to give a better understanding of other options available for disaster management personnel and policy makers in Nigeria that may have limited knowledge of animal health or environmental science.

Keywords: Swine, poultry, carcass disposal, disaster management, epizootics, Nigeria

Introduction

Animal agriculture comprises a substantial portion of the overall agricultural sector in West Africa; where its contribution to the agricultural GDP exceeds 25 per cent (Kamuanga *et al*., 2008). In Nigeria, the sector contributes about 6-8 per cent of her national GDP and 20-25 per cent of total agricultural GDP (NBS, 2015). The common animals reared and slaughtered for meat in Nigeria include cattle, goats, sheep, pigs and poultry camel, buffaloes, donkeys, horses, rabbits and other games and forest animals (Addas *et al*., 2010).

The management of these animals is becoming problematic in the face of emerging climatic variables. The increasing temperature and relative humidity occasioned by changing climates have resulted in cases of death as a result of heat stress (Onyimonyi *et al*., 2013). The increasing concentration of modern production operations in monogastric animals and the mobility of the ruminants such as cattle, sheep and goats increase Nigeria's vulnerability to high death losses due to disease outbreaks. Animal disease-related disasters such as Foot and Mouth Disease (FMD) outbreaks in Taiwan in 1997, and in the United Kingdom (UK) in 2001 generated millions of dead swine, sheep, and cattle carcasses (Wilson and Tsuzynski 1997; DEFRA, 2001). The economic impact of the FMD outbreak was estimated at 4.1 billion pounds, or 0.50 per cent of the UK's Gross Domestic Product for 2001 (Ellis, 2001). Similarly, outbreaks of emerging and re-emerging diseases in Nigeria such as African Swine Fever and Highly Pathogenic Avian Influenza (HPAI) in 1997 and 2006 resulted in large number of dead swine and poultry with concomitant financial loses (FAO, 1998; FAO, 2017).Whenever livestock die in large numbers, it poses daunting carcass disposal challenges regardless of the cause of mortality (USDA, 2004). It thus implies that a rapid and effective disease eradication response should be vital to minimizing livestock losses, economic impacts, and public health hazards.

For the new or exotic diseases, rapid slaughter and disposal of the affected animal are essential and forms important part of effective disease eradication strategies. Whether the introduction of a highly infectious foreign animal disease agent is accidental or intentional, industry and public sector prevention and mitigation efforts are usually not able to protect the public from significant adverse consequences (Ellis, 2001). Therefore, proper animal carcass disposal procedures should form an integral part of preventing further spread of diseases, which subsequently will help minimize the adverse economic impact from such occurrences. In Nigeria, natural disasters such as flooding are infrequent and usually a result of normal meteorological occurrences. Expectations for timely disposal of animal carcasses whenever it occurs means that proper plans must be in place. Animal carcass disposal issues can create logistical and health related problems while managing large-scale animal disaster events. In Nigeria, when disease challenges or natural disasters are not properly managed and animals die in large numbers, how are the carcass of such animals disposed? It is a fact that before problems can be solved, they must be identified and properly understood.

Therefore, the purpose of this paper was to highlight carcass disposal methods in Nigeria in major epizootics such as ASF and HPAI outbreaks. A review of current internationally accepted carcass disposal techniques was done, with their strengths and weaknesses summarized. This was with a view to providing a better understanding of the options available for disaster management personnel and policy makers in Nigeria that may have limited knowledge of animal health or environmental science.

The two animal disease disasters in Nigeria

African swine fever

According to Khan and Line (2010), African Swine Fever (ASF) is a highly contagious viral disease of domestic pigs that manifests itself as a haemorrhagic fever. The causative agent of ASF is a unique, enveloped, cytoplasmic, double-stranded DNA arbovirus, which is the sole member of the family *Asfarviridae* (Blood *et al*., 2007). Although it was generally considered that there is only one serotype of ASF virus, recent studies have reported 32 ASFV isolates in eight different serogroups based on a haemadsorption inhibition assay (Malogolovkin *et al.*, 2015).The catastrophic effect of this disease on pig production, from household to commercial level, has serious socioeconomic consequences and implications for food security (FAO, 2000). It is a serious transboundary animal disease with the potential for rapid international spread (FAO, 2001).

In Nigeria, an outbreak of ASF occurred in 1973 in a piggery in Abeokuta, Ogun State where all the 3000 pigs in the farm died from the disease (FAO, 1998). In October 1997, ASF was reported in Benin, rapidly followed by Togo and in September 1997 the disease surfaced in free-ranging pigs in four local government areas of Ogun State, of Nigeria that have common borders with Benin Republic. The disease was first seen in villages alongside the lagoon passing into Nigeria from Benin Republic (FAO, 1998).

According FAO (1998), dead pig carcasses were seen in the lagoon and there was evidence that boats were traveling along the lagoon selling pig meat in Badagry Market and nearby villages. By December 1997, ASF was reported in Badagry in Lagos State, Nigeria and from the Lagos and Ogun State foci, the disease spread to Osun, Oyo, Ondo, Ekiti, Edo, Delta, Anambra, Enugu, Abia, Rivers, Bayelsa, Akwa-Ibom, Cross-River, Benue, Kaduna and Plateau States of Nigeria. By October 1998, about 125,000 pigs had died of the disease in nine states resulting in estimated financial loss of ₦1.0 billion.

FAO (1998) noted that in Benue State which accounts for about 21 per cent of the national swine herd, 3,108 pig farmers in 20 out of the 23 Local Government

Areas of the State were affected and 78 per cent of the 98,443 affected pigs died of ASF at an estimated loss of ₦ 335,954,000 ($933, 205.56). The national average monetary loss per pig rearing household was estimated at ₦ 55,655 ($154.60). Apart from the immense financial losses from the disease, the outbreaks led to lack of capital for restocking, loss of confidence by pig farmers in the profitability of pig production as well as had demoralizing effects on pig marketers, loaders and pig processing enterprises and also resulted in loss of jobs.

No vaccine against ASF is presently approved in Nigeria. Therefore, the only available option for eradication of the disease is stamping out by slaughter and disposal of all infected and potentially infected pigs (FAO, 2000; FAO, 2001). Thus, all pigs on infected premises (IPs) and dangerous-contact premises (DCPs), or in a larger area if necessary, must be slaughtered immediately, whether they are obviously diseased or not (FAO, 2017). Animal owners are mandated to collect and confine their pigs a day before the slaughter team arrives in the affected farms. The animals are slaughtered by methods that take account of animal welfare and the safety of operatives. The stamping-out approach therefore requires technology for animal carcass disposal as an integral component. These technologies and proper disposal methods are basically lacking in Nigeria.

Highly Pathogenic Avian Influenza (HPAI).

Highly pathogenic avian Influenza is a contagious generalized viral disease of domestic poultry. The disease in avian species ranges clinically from inapparent to a rapidly fatal disease characterized by gastrointestinal, respiratory and/or nervous signs in susceptible species (Khan and Line, 2010). Wild aquatic birds, waterfowls and seabirds serve as important reservoirs but rarely show clinical signs.

Influenza viruses are found predominantly in waterfowls (Stallknecht and Shane, 1988; Alexander, 2000). The original virus that spread to humans in 1997 was first detected in Guangdong, China in 1996. This H5N1 virus was eradicated by the culling of all domestic poultry in Hong Kong. Different reassortant of this virus however continued to emerge and spread to different regions of the world (Alexander, 2000). Highly Pathogenic Avian Influenza causes respiratory disease and deaths in domestic birds and in farmers and consumers that were inappropriately exposed to aerosols generated from handling chickens. The virus appears most threatening, acquiring unprecedented capacity to cause high proportion of death in birds and to cause death and be transmitted among wild species, including domestic cats (Kuiken *et al*., 2004). There is fear that the magnitude of the virulence and pathogenicity of the H5N1 virus is yet to manifest until a pandemic strain evolves (Oladokun *et al*., 2012). The initial incidence of the disease in Hong Kong, 1997 was prelude to the 2003 sporadic outbreaks in Asia and was the precursor of the virus that was detected in Nigeria which also spread to other African countries including Egypt, Togo and Côted'Ivore (Monne *et al*., 2007).

In January 2006, a report of an outbreak of an unknown disease at Sambawa farms Jaji, Kaduna state was received by the National Veterinary Research Institute, Vom, Nigeria (Oladokun *et al*., 2012). According to the author, following laboratory analyses, the virus isolated was typed as Influenza A (Avian Influenza), which was subsequently confirmed by the OIE, FAO and National Reference Laboratory for Newcastle disease and Avian Influenza viruses in Padova Italy, as HPAI (H5N1) based on the amino acid sequences (PQGERRRKKRGLFG) at the cleavage site of Haemagglutinin gene (Joannis *et al.*, 2006). The result of the confirmation of the diagnosis and sub typing was received on February 6, 2006 and a public and formal notification of the outbreak in Nigeria was made on February 8, 2006.

As it applies to ASF, vaccination is yet to be approved for HPAI in Nigeria and stamping out by slaughter and disposal of all infected and potentially infected birds is currently the eradication policy. Although there is paucity of information on the actual number of birds that that died in 2006 when Nigeria experienced the worst avian influenza, Robert *et al*. (2006) however, included Nigeria among the countries that lost, slaughtered or disposed millions of birds as a result highly pathogenic H5N1 incursions in birds.

Statutory regulations of dead animal carcass disposal in Nigeria

According to FAO (2001), pigs' carcass in ASF epizootics should be disposed in such a way that the carcasses no longer constitute a risk for further spread of the pathogen to other susceptible animals by direct or indirect means, such as carrion eaters, scavengers or through contamination of food or water. Onyimonyi *et al.* (2013) reported that Animal Diseases Act of Nigeria (1990) provides that where any animal dies of a disease or is slaughtered in accordance with its provisions or is slaughtered otherwise than in accordance with the provisions of this Act and its carcass is in the opinion of the veterinary officer infected with disease, such carcass shall be disposed-off by burning or in such manner as the veterinary officer may direct. The Act provides for a punishment of three-month imprisonment or a fine of ₦250 ($0.69) for any person who is guilty of an offence, non-compliance or contravention of this Act. Again, the report of the Avian Influenza Control and Human Pandemic Preparedness and Response Project (2007) in Nigeria, identified the following technologies as reliable for carcass disposal/pathogen inactivation: rendering, incineration, compositing, burial, land filling and alkaline hydrolysis.

Onyimonyi *et al.* (2013), noted that enforcement of the relevant provision of the statutes mentioned above is practically not in place as no prosecution of any offender of the provisions of these statues is known. Again, statutory regulations on disposal of dead animal carcass in Nigeria appear not to discuss the disposal of dead animal carcasses where the cause of death is not disease (Onyimonyi *et al*., 2013). This is in spite of the fact that there are apart from disease outbreaks, many situations that could result in death of large number of animals. These practices no doubt will certainly promote the spread of HPAI or ASF through movement of the infected chickens and pigs, contaminated carcasses and pork products especially during outbreaks.

Carcass disposal methods in ASF and HPAI outbreaks in Nigeria

In Nigeria, there is no available record or proper documentation on how animal carcasses are disposed during diseases or natural disasters. Nigerian disaster management agency, the National Emergency Management Agency (NMA), has a mandate to coordinate resources towards efficient and effective disaster prevention, preparedness, mitigation and response in disaster situations in the country. This mission notwithstanding, it is doubtful if the agency played any significant role during ASF and or HPAI pandemics in Nigeria. This is in view of the fact that none of the farmers that affected and was interviewed orally acknowledged this role and to the best of our knowledge there is no available literature to this regard.

Therefore, probably due to lack of incentives from government and logistics of handling large number of animals that die and or destroyed in major epizootics, on the farm burial, burning and incineration in farms, leaving to rot and feeding to dogs of dead carcasses were reported as the most practiced methods of disposing dead animals in Nigeria (Ja'afar- furo *et al*., 2008; Onyimonyi *et al*., 2013). Other noted improper methods of disposing pig carcasses in the country during these disaster events include selling of dead/dying pigs to unsuspecting buyers, throwing them into lagoons/rivers or bushes (FAO, 1998). Affected farmers also slaughtered and sold these pigs in markets and gave some to their neighbours (FAO, 1998; Onyimonyi *et al*., 2013). Although burying, burning or incinerating are internationally accepted methods, they were neither done in accordance with the recommendations of OIE (2003) nor constitutional guideline (Onyimonyi *et al*., 2013).

Animal carcass disposal techniques: Merits and demerits

Burial

Disposal by burial involves excavating a trough into the earth, placing carcasses and covering with the excavated material (USDA, 2004). Two burial methods are commonly recognized for animal carcasses; trench and open pit (FAO, 2001).

Relatively little expertise is required to perform trench burial, and the required equipment is commonly used for other purposes (Nutsch *et al*., 2004). The primary resources required for burial include excavation equipment and a source of cover material. In Nigeria, large-capacity excavation equipment may be available at Ministries of Works or construction companies where they could either be hired or rented. Cover material is often obtained from the excavation process itself and reused as backfill.

In determining the suitability of a site for burial, its characteristics should include soil properties such as slope or topography, hydrological properties, proximity to water bodies, wells, public areas, roadways, dwellings, residences, municipalities, and property lines; accessibility; and the subsequent intended use of the site (USA, APHIS, 1978; Baba *et al*., 2017). Burial in trench is the preferred and commonly used for animal disease eradication efforts (FAO, 2001).

Thus, this method is generally recognized as the preferred disposal method of choice when infectious agents are involved (except where prion agents are suspected), but can also be routinely utilized in natural disasters (Ellis, 2001). This is preferred because the method is generally quicker, cheaper, environmentally cleaner, easiest to organize, and often the most convenient means of disposing of large number of livestock (AUSVET, 1996). Open pit disposal has been the most common method used by commercial poultry producers for disposing of dead animals (Ellis, 2001).

The demerit of burial in disposal pits is that it could poses a threat to groundwater quality resulting from the fact that carcasses can leach contaminants for an undetermined length of time if they do not decompose properly (USDA, APHIS, 1981). Variations in ambient temperature and moisture conditions could slow or speed up the degradation process, thereby affecting environmental contamination possibilities (Sander *et al*., 2002). In disease related disasters such as ASF and HPAI, open trenches could attract scavengers which is highly undesirable. In view of this, freshly closed pits have become the method of choice for the most disease disaster situations. By heaping soil on top of the pit, the weight of the soil acts to stop carcasses from rising out of the pit due to gas entrapment, prevents scavengers from digging up carcasses, helps filter out odors and assists in absorbing the fluids of decomposition (Ellis, 2001). Therefore, in spite of potential logistical and economic advantages of this method, possible effects on the environment and subsequently public health concerns have negatively affected burial as a favoured carcass disposal method (Nutsch *et al*., 2004).

Incineration or burning

Open-air carcass incineration is the burning of carcasses on combustible heaps known as pyres (Kastner and Phebus, 2004). It is an open system of burning carcasses either on-farm with no requirement for transportation of the input material or in collective sites fueled by additional materials of high energy content. According to Ellis (2001), the most critical limiting factors in site location for open air burning are the direction of prevailing winds and selecting locations out of sight of public view. Cost and type of animal to be disposed of also play a role in the success of open-air burning disposal method (Sander *et al*., 2002; Nutsch, 2005). Animals with high fat content such as pigs will burn much faster, with less fuel requirements and cost than poultry that are low in fat and whose feathers do not burn easily. Therefore, in Nigeria, this disposal method could be preferred in ASF than HPAI epizootics.

Burning of animal carcasses produces a solid waste by-product such as bone and ash that is essentially free of pathogens or putrid materials. An exception to this pathogen free assumption is when diseases caused by prion type organisms such as Bovine Spongiform Encephalopathy is suspected (OIE, 2003). Prions must be heated to 850ºC for 2 seconds to be destroyed (SEAC, 1996). Therefore, carcasses from such require addition of combustible material to achieve this high temperature in order to be completely consumed. To promote clean combustion, it is advisable to dig a shallow pit with shallow trenches to provide a good supply of air for open-air burning (MAFF, 2001).

Open air incineration is limited by some factors: The process could contravene environmental standards for air, water and soil (FAO, 2001). It takes an extended period of time and has no verification of pathogen inactivation; could therefore be transmitted from incomplete combusted materials. Notwithstanding, these limitations, open air incineration could be a desirable form of carcass disposal in many disease disaster situations particularly in the tropics.

Due to limitations of open-air incineration method, biological and open pit incineration techniques were developed.

Biological incineration is an efficient disposal method that creates almost no pollution or particulates, and achieves virtually complete oxidation of the carcasses (Baba *et al*., 2017). It is ideal for small number of carcasses located in close proximity to their location, or when the infectious agent must be thoroughly consumed to avoid environmental contamination, such as the prion organism associated with Bovine Spongiform Encephalopathy (Herbert, 2001; de Klerk, 2002). Limiting factors for biological incinerating method include cost, lack of portability, location of existing incinerators, and capacity restraints. Most biological incinerators are located in academic or industrial settings and cannot handle the number of carcasses generated from a large natural or disease disasters such as ASF, and HPAI (Smith *et al*., 2002).
Another type of burning technique is the controlled burning such as in an open pit, or by air curtain incineration (USDA, 2002a). Air–curtain incinerators (also called Trench burners) are a relatively new technology that is now used in many large-scale

natural disasters to burn combustible debris (EPA, 2002). The incinerators consist of large capacity fans driven by diesel engines connected to ducting, which delivers the high velocity air down into a long narrow pit or trench (Kastner and Phebus, 2004).

The advantages of the air curtain incinerators are that they are portable, environmentally friendly with minimal ash or particulates produced and can incinerate vegetative debris from natural disasters (as a fuel source) at the same time the carcasses are consumed (Brglez, 2003). The use of the technology is limited by cost of both the incinerators and fuel depending on the material to be incinerated (Baba *et al.*, 2017).

Composting

According to Mukhtar *et al*. (2004), carcass composting is a natural biological decomposition process that takes place in the presence of oxygen (air). It is a controlled decomposition of carcass materials conducted in either open or closed systems. This method involves the above ground decomposition of animal carcass over a period of time and may be done when soil conditions do not facilitate adequate burial procedures. It preferably requires prior grinding of tissues and addition of organic material for microbial maintenance and mixing or aeration which assures homogeneous decomposition (OIE, 2003). Decomposition occurs when organic materials go through a "slow cooking" process as heat and microorganisms consume the organics and consists of two stages, a primary high temperature active stage, and a secondary lower-temperature “curing” or stabilization stage (Ellis, 2001). The primary phase of composting takes 2-3 months and the secondary phase another 2-3 months (NCDENR, 1998). The end result of the process is the production of carbon dioxide, water vapor, heat and compost. Under optimum conditions, during the first phase of composting the temperature of the compost pile increases to 70°C (OIE, 2003), the organic materials of mortalities break down into relatively small compounds, soft tissue decomposes, and bones soften partially. In the second phase, the remaining materials (mainly bones) break down fully and the compost turns to a consistent dark brown to black soil or “humus” with a musty odor containing primarily nonpathogenic bacteria and plant nutrients (Micozzi, 1991).

Compost is considered to be one of the more environmentally friendly forms of carcass disposal, because it is in effect a form of recycling. It is applicable for many natural disaster situations and is routinely used in the commercial poultry industry today as an accepted form of disposal and can be applied to large animals in some cases, especially swine, but is not appropriate when disease biosecurity is an issue (USDA, 2002a). The merit of carcass composting includes the fact that initial startup costs are minimal as it can occur in either bins or in windrows (deposited in a straight line within a field or pasture). Secondly, the end product can be utilized as fertilizer material or a soil additive. Composting disadvantages are that the process can be complex and requires an appropriate site, proper management and the proper supplies such as wood chips, sawdust and biosolids (Mukhtar *et al*., 2004). It is a slow process (months) which requires some monitoring throughout the process, and is usually not appropriate for disease situations particularly in large animals because the causative organisms may not be destroyed immediately (AUSVET, 1996). It may be difficult to insure a constant temperature throughout the material for the total time period. Although the composting process and the natural decomposition of the animal serve to reduce the disease agents present, verification of the effectiveness of pathogen inactivation may not be easy to achieve.

Rendering

According to Giles (2002), rendering of animal mortalities involves conversion of carcasses into three end products namely, carcass meal (proteineous solids), melted fat or tallow, and water—using mechanical processes (e.g., grinding, mixing, pressing, decanting and separating), thermal processes (e.g., cooking, evaporating, and drying), and sometimes chemical processes (e.g., solvent extraction). The main carcass rendering processes include size reduction followed by cooking and separation of fat, water, and protein materials using techniques such as screening, pressing, sequential centrifugation, solvent extraction, and drying (Mummert, 2001; Auvemann *et al*., 2004). Resulting carcass meal can sometimes be used as an animal feed ingredient. If prohibited for animal feed use, or if produced from keratin materials of carcasses such as hooves and horns, the product will be classified as inedible and can be used as a fertilizer and tallow used in livestock feed, production of fatty acids, or can be manufactured into soaps (USDA, 2002b).

There are two primary methods of rendering. The older method uses steam under pressure (with a grinding process) in large closed tanks. A second and newer method is dry rendering, which cooks the material in its own fat by dry heat in open steam-jacketed drums (EPA, 2001).

Rendering is considered an environmentally friendly method of disposal because it recycles the animal protein from the carcasses back into a usable form as meat or bone meal. The environmentally friendly concept, along with the production of a marketable product is the main advantages of rendering. Limitation include the fact that rendering is not always appropriate for disease situations because the carcasses must be transported to the plant, some species are not amendable to efficient rendering practices, and many areas, there is lack of rendering facilities (Baba *et al*., 2017).

Licensed Commercial Landfill

The use of landfills for carcass and material disposal may be an option (Sander *et al*., 2002). This process involves deposition of animal carcasses in predetermined and environmentally licensed commercial sites. The necessary equipment, personnel, procedures and containment systems already in place and may be useful. Because a landfill site is usually in existence prior to a time of emergency, set-up time would in theory be minimal. However, the transport of carcasses to these locations may pose some risk of disease spread. Disadvantage of this method is that the area is normally open and uncovered for extended periods, there is therefore a potential emission of aerosols, and thus resistance from the public to such an approach (OIE, 2003). However, because the site has been previously licensed, all environmental impacts such as leachate management, gas (landfill gas) management, engineered containment, flooding, and aquifers would have already been considered.

Fermentation

Lactic acid fermentation, a process that provides a way to store carcasses for at least 25 weeks and produce an end product that maybe both pathogen-free and nutrient-rich. Lactic acid fermentation is commonly referred to as pickling because microorganisms are inactivated and the decomposition process ceases when the pH is reduced to approximately 4.5 (Cai *et al*., 1994). Thus, low pH prevents undesirable degradation processes.

The process of lactic acid fermentation is simple and requires little equipment such a tank and grinder (Erickson *et al*., 2004). According to Tibbetts *et al.* (1987), the size of the container does not influence fermentation, but the use of a non-corrosive container is desirable to avoid corrosion.

The equipment could be any sized noncorrosive container provided it is sealed and vented for carbon dioxide release (Damron, 2002). During this process, carcasses can be decontaminated and there is a possibility of recycling the final products into feedstuff. Fermentation products can be stored until they are transported to a disposal site. Carcasses are ground into smaller pieces to facilitate fermentation as smaller particles absorb lactic acid better than whole carcasses (Johnston *et al*., 1998). Furthermore, the mixture of ground carcasses permits better homogenization of the fermented material (Erickson *et al*., 2004).

A fermentable carbohydrate source such as sucrose, molasses, whey, or ground corn is added to the ground carcasses. The ratio between fermentable carbohydrate and carcasses is 20:100 by weight (Blake and Donald, 1995). The sugar is fermented to lactic acid by indigenous bacteria such as *Lactobacillus acidophilus*. This bacterial species is naturally present in the intestine of poultry; but for all animal species, including poultry, it is desirable to provide an additional inoculation of *Lactobacillus acidophilus* culture. The production of lactic acid creates acidification, which decreases the pH of the carcass material. According to Tamim and Doerr (2000), the temperature for fermentation should be above 30°C (86°F) to obtain a biologically safe final product with a pH of less than 4.5. If lactic acid fermentation incompletely acidifies the carcasses, a mineral or organic acid should be directly added. Under optimal conditions, fermentation reduces the pH from 6.5 to 4.5 within 48 hours (Morrow and Ferket, 2001). This decrease in pH preserves the nutrients and permits the carcasses to be stored for several months before rendering or use for other purposes (Sander *et al*., 1995).

Merits of lactic acid fermentation include decontamination of carcasses, possibility of recycling into a feedstuff and storage and its potential mobile process.

The challenges with lactic acid fermentation are complete pathogen containment, fermentation tank contamination, corrosion problems and the need for carbohydrate source and *Lactobacillus acidophilus* culture.

Alkaline Hydrolysis.

Alkaline hydrolysis represents a relatively new carcass disposal technology. It has been adapted for biological tissue disposal such as in medical research institutions as well as small and large animal carcass disposal (Thacker and Kastner 2004).

Alkaline hydrolysis consists of treating carcasses or tissue in an aqueous alkaline solution at elevated temperatures under pressure. It converts proteins, nucleic acids, and lipids of all cells and tissues into a sterile aqueous solution of small peptides, amino acids, sugars, and soap (OIE, 2003). What remains are the mineral constituents of the bones and teeth. This undigested residue, which typically constitutes approximately two per cent of the original weight and volume of carcass material, is sterile and easily crushed into a powder that may be used as a soil additive (WR2, 2003). Alkaline hydrolysis is carried out in a tissue digester that consists of an insulated, steam-jacketed, stainless-steel pressure vessel with a lid that is manually or automatically clamped and operates at 150°C for three hours (OIE, 2003;Thacker and Kastner, 2004).

The temperature conditions and alkali concentrations of this process destroy the protein coats of viruses and the peptide bonds of prions (Taylor and Wood gate, 2003). It therefore completely inactivates pathogens with the exception of prions where infectivity is reduced and is environmentally friendly.

Advantages of alkaline hydrolysis asa method of animal carcass disposal include the following:

i. Combination of sterilization and digestion into one operation,
ii. Reduction of waste volume and weight by as much as 97 per cent,
iii. Production of limited odor or public nuisances and elimination of radioactively contaminated tissues.

Disadvantages of alkaline hydrolysis process of animal carcass disposal include the fact that at present it has limited capacity for destruction of large volumes of carcasses and there are issues regarding disposal of its resultant effluent (Thacker and Kastner, 2004).

Special Considerations for Prion Diseases

One of the problems in demonstrating the effectiveness of the inactivation of prions (a small protein which is believed capable of infecting cells and causing self to be replicated though it does not contain nucleic acid) is the lack of a simple, rapid and inexpensive test for the presence of the infective agent, especially at low concentrations (OIE, 2003). The ultimate test is bioassay in a sensitive detector species by an efficient route, but usually this is only relevant in research. Typically, this is done using panels of mice bred to be susceptible to particular types of transmissible spongiform encephalopathies (TSEs). However, it must be recognized that the mouse to cattle species barrier has been demonstrated to be 500, therefore affecting sensitivity.

Although rendering at 133°C and three bars of pressure for 20 minutes is a defined standard, reductions of infectivity by this technology are in the order of 1:200 - 1:1000 (OIE, 2003). Commercial incinerators have an inactivation rate of one million-fold, while burning on pyres has a reduction rate of 90 per cent. (It should be noted that pyres are not suitable for sheep because of the wool and fat.) Alkaline hydrolysis produces a 3-4 log reduction in infectivity over a three-hour period. Landfill and deep burial are suggested to have a reduction in infectivity of 98 - 99.8 per cent over three years. Based on this information, rendering, incineration, and alkaline hydrolysis are the most reliable technologies at this time (OIE, 2003; USDA, 2004).

The significance of small amounts of infectivity become evident when one considers that experimentally it has been shown that exposure of sensitive species to as little as 1.0, 0.1 or even 0.01 grams of infected nervous tissue can induce infection (OIE, 2003).

Given all of the above, it must be recognized that no process has been demonstrated to be 100 per cent effective in removing TSE infectivity and there will be some residual levels of infectivity remaining after treatment.

Selecting carcass disposal method

Animal mortality is an integral part of livestock farming and proper disposal of these mortalities is necessary for effective disease control measures (Baba *et al.*, 2017).The most effective strategy for large scale animal disease disaster events will be those that exploit every available and suitable option to the fullest extent possible regardless of what those options might be (Nutsch, 2005). The selection of a preferred method of disposal will usually be determined by the cause of death (Ellis, 2001). If the death is due to an infectious organism, then the method that most efficiently prevents further disease spread is usually the preferred choice. When a natural disaster is the cause of death, the carcass disposal method chosen should be the most environmentally acceptable (USDA, 1991).

Disaster managers and policy makers should understand each disposal technology available and thus equip themselves with a comprehensive knowledge (Baba *et al*., 2017). Such awareness implies an in adept understanding of an array of factors for each technology, including the principles of operation, logistical details (scope of disaster), personnel requirements, likely costs, environmental considerations, disease agent considerations, advantages and disadvantages. Another consideration is that when public health issues are involved, mitigation of human death or disease may force the utilization of a method which may not be the preferred method of choice, when all other factors are considered equal (Ellis, 2001).

In Nigeria, ignorance of farmers and non-enforcement of relevant laws have resulted in potentially greater health and environmental risks due to illegal methods of carcass disposal particularly in major epizootics such as ASF and HPAI. There is need for new methods of carcass disposal such as rendering and composting that have gained global popularity due to their end product utility to be developed in Nigeria. Finally, it is hoped that the government or public sector realizes the importance of the inclusion of animal health component in any emergency response plan.

Acknowledgments

The authors appreciate Dr C.B. Abonyi of the Department of English and Literary Studies, University of Nigeria, Nsukka for language editing of this article.

Disclosure of interest

The authors report no conflict of interest

References

Addas PA, Midaun A, Milka M, Tizhe MA. 2010. Assessment of Abattoir Foetal Wastage of cattle, Sheep, and Goat in Mubi Main Abattoir Adamawa State, Nigeria. World J. Agric. Sci. 6(2):132-137.

Alexander DJ. 2000. A review of Avian influenza in different bird species. Vet Microbiol. 74: 3-13.

AUSVET. 1996. Destruction plan, Agriculture and Resource Management Council of Australia and New Zealand. Available at https://www.google.com/search?client=firefox-b-d&q=Destruction+plan%2C+Agriculture+and+Resource+Management+Council+of+Australia+and+New+Zealand. Accessed August 21, 2019

Auvemann, B., Kalbasi, A. and Ahmed, A. 2004. Rendering. In: Carcass Disposal: a comprehensive review. Report prepared by the National Agricultural Biosecurity Center Consortium, Carcass Disposal Working Group for the USDA Animal & Plant Health Inspection Service Per Cooperative Agreement 02-1001-0355-CA

Baba, I. A., Banday, M. T., Khan, A. A., Khan, H. M. and Nighat, N. 2017. Traditional methods of carcass disposal: a review. J Dairy Vet Anim Res. 5(1):21-27. DOI: 10.15406/jdvar.2017.05.00128. Available at https://medcraveonline.com/JDVAR/JDVAR-05-00128.php. Accessed August 16, 2019.

Beltrán-Alcrudo, D., Arias, M., Gallardo, C., Kramer, S. & Penrith, M.L. 2017.African swine fever: detection and diagnosis – A manual for veterinarians. FAO Animal Production and Health Manual No. 19. Rome. Food and Agriculture Organization of the United Nations (FAO); pp. 88.

Blake, J.P. and Donald, J.O. 1995. Rendering a disposal method for dead birds (Circular ANR-923). Alabama: Auburn University and Alabama Cooperative Extension Service. Available at http://www.aces.edu/pubs/. Accessed August 16, 2019.

Blood, D.C., Studdert, V.D. and Gay, C.C. 2007. Comprehensive Veterinary Dictionary, 3rd edition. Laboratory Services. Saunders Elsevier, Edinburgh, London, New York, Philadelphia, St. Louis, Sydney, Toronto.

Brglez, B. 2003. Disposal of poultry carcasses in catastrophic avian influenza outbreaks: A comparison of methods (technical report for Master of Public Health). Chapel Hill: University of North Carolina.

Cai, T., Pancorbo, O.C., Merka, W.C., Sander, J.E., and Barnhart, H.M. 1994. Stabilization of poultryprocessing by-products and waste and poultry carcasses through lactic acid fermentation.Journal of Applied Poultry Research, 3 (1), 17-25.

Damron, B.L. 2002. Options for dead bird disposal (Fact Sheet AN-126). Florida:University of Florida Cooperative Extension. Available at http://edis.ifas.ufl.edu/BODY_AN126. Accessed August 16, 2019.

DEFRA. 2001. Department of Environment Food and Rural Affairs (DEFRA), Foot and Mouth Disease Regulations, General License for Movement of Carcasses.

de Klerk, P.F. (2002). Carcass disposal: lessons from the Netherlands after the foot and mouth disease outbreak of 2001. Revue Scientifique et Technique Office International des Épizooties. 21 (3): 789-796.

Ellis, D. 2001. Carcass disposal issues in recent disasters, accepted methods, and suggested plan to mitigate future events (applied research project for Master of Public Administration). San Marcos, Texas: Texas State University-San Marcos (formerly Southwest Texas State University).

EPA. 1995. Environmental Protection Agency (EPA), “Development document for the proposed Revisions to the national Pollutant discharge elimination system regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations”, Available at http://www.epa.gov/unix0008/water/wastewater/cafohome/cafodownload/cafodocs/DDChapters8..pdf. Accessed April 9, 2018

EPA 2002. Office of Solid Waste and Emergency Response. Municipal solid waste in the United States: 2000 facts and figures executive summary (EPA530-S-02-001).

Erickson, L.E., Yayet, E., Kakumannu, B. K. and Davis, L.C. (2004). Lactic acid fermentation. In: Carcass Disposal: a comprehensive review. Report prepared by the National Agricultural Biosecurity Center Consortium, Carcass Disposal Working Group for the USDA Animal & Plant Health Inspection Service Per Cooperative Agreement 02-1001-0355-CA

FAO 1998. African swine fever in West Africa: Togo, Senegal, Gambia and Guinea-Bissau. [French] Mission report from 1 to 16 June 1998. (1998a) Available at: http://www.fao.org/docrep/field/382969.htm. Accessed April 9, 2018.

FAO 2000. Food Agricultural Organization of the United Nations. Recognizing African swine fever. A field manual. FAO Animal Health Manual. Available at http://www.fao.org/docrep/004/x8060e00,htm. Accessed April 9, 2018.

FAO 2001. Food Agricultural Organization of the United Nations. Manual on the preparation ofAfrican Swine Fever Contingency Plans. FAO Animal Health Manual No. 11.Available at http://www.fao.org/empres.pdf. Accessed April 9, 2018.

FAO2013. Food Outlook Biannual Report on Global Food Markets. ISSN: 0251-1959. Available at http://www.fao.org/3/a-I5703E.pdf. Retrieved on February 23, 2018.

FAO 2017. African Swine Fever: Detection and Diagnosis. A manual for Veterinarians. Food and Agricultural Organization of the United Nations, Rome.

Giles, D. 2002. Rendering: The invisible industry. Animal Issues, 33 (3). Available at http://www.api4animals.org/doc.asp?ID=1318. Accessed August 22, 2019.

Guan Y, Peiris JS, Laptov, A.S., Ellis, T.M., Dyrting, K.C., Krauss, S., Zhang, L.J., Webster, R.G. and Shortridge, K.F. 2002. Emergence of multiple genotypes of H5N1 avian influenza viruses in Hong Kong SAR. Proc Natl Acad Sci U S A. 2002 Jun 25;99(13):8950-5. Available at https://www.ncbi.nlm.nih.gov/pubmed/12077307. Accessed August 23, 2019.

Herbert, D. (2001). Five million carcasses and counting. Available at http://edition.cnn.com/2001/WORLD/europe/01/23/britain.cow/. Accessed February 13, 2018

Ibrahim W., M., Abdul., Sackey, A. K. B. and Oladele, S. B. 2013. Survey for Highly Pathogenic Avian Influenza from Poultry in Two Northeastern States, Nigeria. Veterinary Medicine International 2013: 2013:531491. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/ PMC3725891/. Accessed August 03, 2019. doi: 10.1155/2013/531491

Ja`afar-Furo, M.R. Balla, H.G. Tahir A.S. and Haskainu, C.2008. Incidence of Avian Influenza in Adamawa State, Nigeria: The Epidemiology, Economic Losses and the Possible Role of Wild Birds in the Transmission of the Disease. Journal of Applied Sciences, 8: 205-217.DOI:10.3923/jas.2008.205.217. Available at https://scialert.net/abstract/?doi=jas.2008.205.217. Accessed August 23, 2019.

Jibrin, A.H.,Bello, M.B., Bello, S.M., Saheed, Y. Balla, F.M. 2016.Biosecurity Measures and Constraints among Rural Poultry Farmers in Zamfara State, Nigeria. Animal and Veterinary Sciences 2016; 4(4): 47-51doi: 10.11648/j.avs.20160404.11 available at: http://www.sciencepublishinggroup.com/j/avs. Retrieved on March 3,2018.

Joannis, T., Lombin L.H., De Benedictis, P., Cattoli, G. and Capua, I. 2006. Confirmation of H5N1 avian influenza in Africa. Vet Rec. 158 (9):309-10. DOI:10.1136/vr.158.9.309-b

Johnston, L.J., Robinson, R.A., Clanton, C.J., Goyal, S.M., Ajariyakhajorn, C., and Heilig, D.M. 1998. Homogenization for disposal of dead piglet carcasses. Applied Engineering in Agriculture, 14 (2), 183-186.

Kahn, C.M. and Line, S. 2010. Avian Influenza. In: The Merck Veterinary Manual. KAHN C.M and LINE S. (Ed), 10th edition. Merck and Co. Inc, Whitehouse Station N.J., USA: 1705 -1706.

Kamuanga, M.J., Somda, J., Sanon, Y., Kagone, H., Zoundi, J.S. and Hitimana, I. 2008. Livestock and regional market in the Sahel and West Africa: Potentials and challenges. Study carried out within ECOWAS Commission and SWAC/OECD initiative in partnership with the CILS, UEMOA and ROPA. Available at http://www.occd.org/dataoccd/10/8/41848366.pd. Accessed August 21, 2019.

Kastner, J. and Phebus, R. 2004. Incineration. In: Carcass Disposal: a comprehensive review. Report prepared by the National Agricultural Biosecurity Center Consortium, Carcass Disposal Working Group for the USDA Animal & Plant Health Inspection Service Per Cooperative Agreement 02-1001-0355-CA

Kuiken T, Rimmelzwaan G., van Riel, D., van Amerongen, G., Raars, M., Fouchier, R. and Osterhause, A. 2004. Avian H5N1 influenza in cats. Science. 306: 241. Available at https://www.ncbi.nlm.nih.gov/pubmed/15345779. Accessed August 23, 2019.

MAFF 2001. Ministry of Agriculture Fish and Food, “Statistics on Foot and Mouth Disease”, HM Government-UK. Available at http://www.maff.gov.uk/animalh/diseases/fmd/statistics.htm. Accessed July 23 2018

Malogolovkin, A., Burmakina, G., Titov, I., Sereda, A., Gogin, A., Baryshnikova, E. &Kolbasov,D.2015. Comparative analysis of African swine fever virus genotypes and serogroups. *Emerg Infect Dis.* Feb;21(2):312-5. doi: 10.3201/eid2102.140649. PubMed PMID: 25625574; PubMed Central PMCID: PMC4313636.

Micozzi, M.S. (1991). Postmortem change in human and animal remains: a systematic approach. Springfield, Illinois: Charles C Thomas.

Monne I, Joannis T.M., Fusaro, A., De Benedictis, P., Lombi, L.H., Umaru, H., Egbuji, T., Solomon., P., Obi, T. U., Cattoli, G. and Capua, I. 2008. Reassortant Avian influenza virus (H5N1) in Poultry, Nigeria, 2007. Emerg Infect Dis. 14 (4): 637-640.

Morrow, M.W.E. and Ferket, P.R. 2002. Alternative methods for the disposal of swine carcasses (Animal Science Fact Sheet ANS01-815S). North Carolina: North Carolina State University.
Available at
http://mark.asci.ncsu.edu/Publications/factsheets/815s.pdf. Accessed August 24, 2019.

Muhangi, D., Masembe, C., Emanuelson, U., Boqvist, S., Mayega, L., Ademun, R.O., Bishop, R.P., Ocaido, M., Berg, M. and Karl Ståhl, k. 2015. A longitudinal survey of African swine fever in Uganda reveals high apparent disease incidence rates in domestic pigs, but absence of detectable persistent virus infections in blood and serum. BMC Veterinary Research (2015) 11:106.

Mukhtar, S., Kalbasi, A. and Ahmed, A. 2004. Compositing. In: Carcass Disposal: a comprehensive review. Report prepared by the National Agricultural Biosecurity Center Consortium, Carcass Disposal Working Group for the USDA Animal & Plant Health Inspection Service Per Cooperative Agreement 02-1001-0355-CA

Mummert, D. 2001. Application of hazardous waste site methodology to large scale dead poultry and farm animal recovery operations. American Industrial Hygiene Association 2001 Abstracts. Unusual Problems/Flexible Solutions (Papers 32-37, 32). The IT Corporation. Findlay, Ohio. http://www.aiha.org/abs01/01unu.html. Accessed August 23, 2019.

NBS (2015). Nigerian gross domestic product report. Quarter two, issue 6.

NCDENR 1998. Division of Waste Management, Solid Waste Section, Disaster Debris Management, “A Fact Sheet for Composting Flood-related Animal Mortalities”. Available at http://www.p2pays.org/ref/03/02750.pdf.Accessed July 19, 2017.

Nutsch, A. 2005. Carcass disposal options: a multidisciplinary perspective. Proceedings of the Institute of Food Technologists' First Annual Food Production and Defense Research Conference. November 3-5, 2005, Atlanta, Georgia.

Nutsch, A., Spine, M., Kastner, J. and Jones, D. D. 2004. Burial. In: Carcass Disposal: a comprehensive review. Report prepared by the National Agricultural Biosecurity Center Consortium, Carcass Disposal Working Group for the USDA Animal & Plant Health Inspection Service Per Cooperative Agreement 02-1001-0355-CA

Obi, T. U. 2014. Trans-boundary animal diseases and our national food security: strategies for control/eradication. In: Animal Disease Control, lecture delivered at the College of Veterinary Surgeons Nigeria Fellowship Programme, University of Nigeria Nsukka Study Centre, October 27-31, 2014.

OIE, 2003.World Organization for Animal Health. Animal carcass disposal. Available at https://www.oie.int/doc/ged/D2964.PDF .Accessed August 16, 2019

OIE (2013). World Organization for Animal Health. African swine fever Technical Disease Card. Available at: http://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/African_Swine_Fever.pdf. Accessed March 3, 2018.

Oladokun, A.T., Meseko, C.A., Ighodalo, E., Benshak John, B, and Ekong, P.S. 2012. Effects of intervention on the control of Highly pathogenic Avian Influenza in Nigeria. The Pan African Medical Journal. 13:14, doi:10.11604/pamj.2012.13.14.1106 Available at https://www.panafrican-med-journal.com/content/article/13/14/full/. Accessed August 03, 2019.

Onyimonyi, A. E, Machebe, N. S. and Ugwuoke, J. 2013. Statutory regulations of dead animal carcass disposal in Nigeria: A case study of Enugu State. African Journal of Agricultural Research. 8:11. 1093-1099. DOI:10.5897/AJAR12.1904.

Plowright, W., Thomson, G.R. and Neser, J.A. 1994. African swine fever, in J.A.W. Coetzer,G.R. Thomson and R.C. Tustin (eds.), Infectious disease of livestock, with special reference toSouthern Africa Vol. 1, pp. 568-599, Oxford University Press, Cape Town.

Robert G. Webster; E. A. Govorkova, M.D. (2006). "H5N1 Influenza-Continuing Evolution and Spread". NEJM. ***355*** *(21): 2174–2177.*doi*:*10.1056/NEJMp068205. PMID 17124014.

Robinson, T.P., Thornton P.K., Franceschini, G., Kruska, R.L., Chiozza, F., Notenbaert, A., Cecchi, G., Herrero, M., Epprecht, M., Fritz, S., You, L., Conchedda, G. and See, L. 2011. Global livestock production systems. Rome, Food and Agriculture Organization of the United Nations (FAO) and International Livestock Research Institute (ILRI), pp. 152.

Sander, J.E., Warbington, M.C. and Myers, L.M. 2002.Selected methods of animal carcass disposal. Journal of the American Veterinary Medical Association, 220 (7), 1003-1005.

SEAC. 1996. Spongiform Encephalopathy Advisory Committee, SEAC FMD WG 5, Environmental Agency (UK), National Centre for Risk Analysis and Options Appraisal, "Comparative BSE Risks to Public Health, from Disposal of " Off-Farm" Ash from Pyres, pp. 1-3.

Smith, S.N., Southall, R., & Taylor, T.L. 2002. Draft operational guidelines - disposal, APHIS Carcass Disposal Manual (15th Draft, 2/22/02). Washington, DC: United States Department of Agriculture, Animal and Plant Health Inspection Service.

Stallknecht DE, Shane SM. (1988). Host range of avian influenza virus in free living birds. Vet Res Commun. 12: 125-41.

Tamim, N.M. and Doerr, J.A. 2000. Fermentation of Broiler Carcasses — Foolproof or Not? Poultry perspectives. 2 (1): 6-7. Available at http://www.wam.umd.edu/~iestevez/extension/pp v2n1.pdf. Accessed July 21, 2017

Taylor and Woodgate 2003. Rendering practices and inactivation of transmissible spongiform encephalopathy agents. Rev. sci. tech. Off. int. Epiz., 2003, 22 (1), 297-310. Available at https://pdfs.semanticscholar.org/2559/c24c7f44988104cf00a3ec21fa535730dd83.pdf Accessed August 23 2019.

Tibbetts, G.W., Seerley, R.W. and McCampbell, H.C. 1987. Poultry offal ensiled with *Lactobacillus acidophilus* for growing and finishing swine diets. Journal of Animal Science, 64, 182-190.

Thacker, H. L. and Kastner, J. 2004. Alkaline hydrolysis. In: Carcass Disposal: a comprehensive review. Report prepared by the National Agricultural Biosecurity Center Consortium, Carcass Disposal Working Group for the USDA Animal & Plant Health Inspection Service Per Cooperative Agreement 02-1001-0355-CA

USDA, APHIS. 1978. Eradication of exotic Newcastle disease in southern California 1971-74 (No. APHIS-91-34). USA: United States Department of Agriculture, Animal and Plant Health Inspection Service.

USDA, APHIS. 1981. Hog cholera and its eradication, a review of U.S. experience (No. APHIS 91-55). USA: United States Department of Agriculture, Animal and Plant Health Inspection Service.

USDA-APHIS-VS, 2001. Chronic Wasting Disease News Release, 1-4.Available at http://www.aphis.usda.gov/oa/pubs/fscwd.html. Accessed August 21, 2019.

USDA, 2002a. Natural Resources Conservation Service, Texas. Catastrophic animal mortality management (burial method) technical guidance. Texas: Texas State Soil and Water Conservation Board. http://tammi.tamu.edu/burialguidance.pdf

USDA. 2002b. Draft of operational guidelines disposal, national animal health emergency management system guidelines. Washington, DC: USDA APHIS.

USDA 2004. Carcass Disposal: a comprehensive review. Report prepared by the National Agricultural Biosecurity Center Consortium, Carcass Disposal Working Group for the USDA Animal & Plant Health Inspection Service Per Cooperative Agreement 02-1001-0355-CA

Wilson, T and Tuszynski C, 1997. "Foot and Mouth Disease in Taiwan- overview", 101st United States Animal Health Association Proceedings, October 18-24, 114-123.

WR2. 2003.Company pamphlet. Indianapolis: Waste Reduction by Waste Reduction, Inc.Available at http://www.wr2.net. Accessed August 16, 2019.

Access this Article in Online

Quick Response Code	Website: www.ijarbs.com
	Subject: Animal Sciences

DOI:10.22192/ijarbs.2020.07.12.018

How to cite this article:
Abonyi, F. O., Machebe, N. S. and Gary A. Flory. (2020). Swine and poultry carcasses disposal methods in major epizootics in Nigeria: available and alternative methods. Int. J. Adv. Res. Biol. Sci. 7(12): 162-174.
DOI: http://dx.doi.org/10.22192/ijarbs.2020.07.12.018