May 2014

HUMANE SOCIETY INTERNATIONAL

An HSI Report: The Welfare of Animals in the Pig Industry

Abstract

The discordance between the behavioral needs of pigs and the life afforded to those raised commercially for the meat industry has created many animal welfare problems. Methods of pig production have changed substantially over the last several decades, and industrialized confinement operations have largely overtaken small, diversified farms. Overcrowded in indoor, barren environments, pigs in commercial production facilities are offered little opportunity to display their full range of complex social, foraging, and exploratory behavior. Behavioral abnormalities, such as tail-biting and aggression, arise due to environmental and social deficiencies. Poor air quality and intensive confinement may lead to health problems, and the lack of individualized attention to each animal compromises their care. Handling and transport for slaughter are highly stressful procedures, and some pigs become so fatigued, injured, or sick that they become nonambulatory, unable to stand and walk on their own accord. Each one of these issues is a significant animal welfare problem in need of immediate redress.

Introduction

Pigs first became used in agriculture when wild boar were domesticated, approximately 9,000 B.C.E.[1] Studies of pigs in natural, unrestricted environments have revealed that they display a rich behavioral repertoire, and have a well-defined social structure. They commonly segregate into small groups, but some pigs, particularly adult and sub-adult males, may be solitary.[2] Pigs build nests in which to rest by selecting a secluded area and collecting grass and small branches.[3,4] Because they have few sweat glands, pigs wallow in mud, using its cooling properties to help them regulate their body temperature.[5] Pigs are omnivores and choose to consume a varied diet of grass, roots, mast (forest nuts, such as acorns), and sometimes earthworms, crustaceans, and insects.[6] Wild boar can live to be 21 years old.[7]

Until the 1960s, even in the United States, farmed pigs were typically raised in extensive systems, on diverse, small- and medium-sized operations,[8] where they were kept on pasture, in dry lots, or with portable housing.[9] When given access to pasture, the animals were provided with small, movable shelters or a centralized barn.[10] Approximately 4,000 m^2 (1 acre) of pasture was provided for every 20 pigs,[11] allowing ample space for the display of most of their natural behavior. Piglets were born twice a year, usually in the fall and in the spring.[12] Straw was used for bedding, providing comfort and warmth.

In contrast, changes in animal agriculture over the last half of the 20th century have drastically altered farming practices and management, and, subsequently, the welfare of domesticated pigs. On the large, commercial operations that are now the norm throughout the world, pigs are primarily confined indoors in industrialized facilities. Pigs raised in these systems are no longer able to exhibit important natural behavior, such as rooting, wallowing, nest-building, and foraging, and are unable to segregate into natural social groups. Scientists have noted that pigs, like other domesticated animals,[13] retain the basic behavioral repertoire of their wild counterparts, despite being domesticated and confined on industrialized facilities.[14]

Industrial Production

Since the mid-20th century, small, extensive farms have given way to massive, commercial pig production facilities.[15,16] Large, more specialized indoor operations benefit from economies of scale.[17] In the 1990s, "megafarms"—those with more than 10,000 breeding sows (female pigs) in one location—became the dominant production type, confining 30% of all sows in the United States and 40% of all pigs raised to slaughter weight.[18] Smithfield Foods, the largest pig producer in the United States[19] and globally,[20] keeps nearly 1.1 million breeding sows, and the next nine top companies have more than 100,000 sows each.[21] In 2012, nearly 1.4 billion pigs were raised and slaughtered globally.[22] A growing number of producers around the world are turning to intensive, industrial farm animal production (IFAP) systems,[23,24] which now account for over half of pig meat production.[25]

Customarily, the pig production cycle begins with the breeding of the sow, either naturally or by artificial insemination. After a 114-day gestation (pregnancy) period, mother sows farrow and nurse their piglets for 2-4 weeks before the litters are prematurely weaned.[26] Following the nursery phase, during which the young animals reach 18.1-27.2 kg (40-60 lb) by approximately 8-10 weeks of age, the young pigs are moved to different facilities for "growing" and "finishing."[27,28] They are considered to be in the growing stage until they reach 54.4 kg (120 lb),[*] at about 3 months of age, and then are in the finishing stage until they reach market weight of 108.9-122.5 kg (240-270 lb),[29] at approximately 6 months of age.[30]

Overcrowding

Pigs on commercial facilities are raised in much smaller spaces than they would normally occupy if permitted to roam freely. Radiotelemetry studies have reported that feral pigs sometimes travel several kilometers (miles) each day.[31] In observations of foraging behavior of domestic pigs in large, outdoor enclosures, members of social groups averaged 3.8 m (12.5 ft) from their nearest neighbor, while herds foraged 50 m (164 ft) or more apart.[32] In contrast, the average space allowance for a pig in a growing/finishing facility is 0.7 m^2 (7.7 ft^2).[33]

Wild and feral pig social groups are small herds composed of both young and adult animals, usually with 2-4 adults,[34,35] but in confinement operations, the typical recommendation is to keep pigs in group pens holding up to 30 animals,[36] some with approximately 1,000 animals under the same roof.[37] Some producers are experimenting with even larger group sizes, with 150-400 or more pigs in one pen.[38] Commercial pig producers often sort animals by size,[39] without regard to family group[40] or previously formed social bonds.

Lack of space and the artificial group structure imposed on intensively confined pigs can negatively influence social interactions. When pigs are sorted into new groups, fighting sometimes occurs, and although serious injuries or death are rare, they can result, especially when one pig is singled out by multiple aggressors.[41] When space is limited, submissive and flight reactions may be less effective in the establishment of social dominance.[42] In contrast, when given ample room, herds usually distance themselves, simply avoiding situations that would lead to aggression and thereby minimizing the frequency of antagonistic interactions.[43,44]

Although animals in any type of production system can suffer from health problems, the dense population of closely confined animals in industrial operations facilitates the transmission of disease.[45] For pigs in the fattening stage of production, respiratory and enteric diseases are common infectious disorders.[46] In fact, one veterinary text book notes that "under commercial conditions few pigs can be expected to reach slaughter weight without contracting some sort of respiratory lesion."[47] In contrast, another popular textbook notes that for pigs in their wild state, "diseases and parasites were almost unknown" due to the "roving nature" of naturally occurring pig populations.[48]

[*] For purposes of this report, the term "hog" will not be used to refer to pigs who weigh more than 54.4 kg (120 lb), as this industry term is not necessarily convention in the scientific literature.

Barren Environment

Pigs are naturally active and inquisitive and have a well-developed exploratory drive.[49] In more natural environments, they spend the greater part of the day collecting and manipulating food items. Behavioral studies have reported that pigs in a forested enclosure occupy more than 50% of their daily time budget with foraging-related activities.[50] In the absence of enriched, interesting surroundings in industrial production facilities, pigs often redirect their natural curiosity to pen fixtures and pen mates. They may begin to nose and bite each other, or simply spend more time inactively.[51,52] Inactivity and unresponsiveness are particularly frequent in confined sows,[53,54] and are indicators of poor welfare associated with lack of stimulation and boredom.[55] Scientists have suggested that artificial environments, such as those found on commercial confinement operations, engender apathy, frustration, and an "enduring sense of boredom."[56,57]

Disharmony between an animal and the environment can also lead to an outbreak of abnormal tail-biting behavior.[58] Tail biting typically starts with one pig playing with, sucking, or chewing on the tail of a pen-mate. Tail-directed behavior can then escalate as tail-biting victims are chased and their tails are further damaged.[59] Not only is tail biting acutely painful, but it can result in injury to the tail base, abscess, and systemic infection.[60,61,62] In severe cases, the hind quarters may be bitten and tail biting can escalate into cannibalistic behavior.[63] To prevent tail biting, the tails of newborn piglets are usually cut off shortly after birth and without any pain relief. When tails are docked too short, pigs may resort to biting the ears of their pen mates instead.[64] Although the behavior is multifactorial and caused by a variety of inter-related elements, many studies have demonstrated that providing straw and other enrichments, e.g. additional space and rooting and nosing substrate, including peat[65] or spent mushroom compost,[66] would largely reduce or even prevent tail-biting behavior.[67,68,69,70,71,72,73]

Ear hematomas are broken blood vessels and bleeding under the skin of the ear. One cause is biting by pen mates. While lancing the wound and bandaging is the most effective treatment, some producers amputate the ear instead by using an elastic band to restrict circulation to the ear.[74] Such "solutions" are not only animal welfare concerns, but fail to address the environmental inadequacies that lead to such problems in the first place.

Bare, Concrete Flooring

Indoor operations are characterized by concrete, slatted floors and steel fixtures.[75] Slatted floors facilitate manure handling—animal waste falls through the flooring into a deep pit below, where it is collected under the facility and often subsequently transferred to an outdoor holding area, such as a lagoon. Bedding, such as straw, is usually eliminated in indoor operations due to cost, difficulty of cleaning, and incompatibility with slatted floors.[76]

Pigs can suffer from lameness and a variety of foot problems, therefore the surface on which they are kept is a key feature affecting their welfare. The initial introduction of slatted floors in production facilities led to hoof disorders such as foot lesions.[77] Although many factors can cause locomotory problems, poorly maintained or slippery flooring are still common causes of physical injuries.[78] In a British survey of indoor and outdoor pig farms published in 2008, pigs allowed outdoor access had a lower prevalence of foot and limb injuries, while those confined indoors on hard, slatted flooring customary in industrial pig production had more bruising, calluses, locomotion problems, and "adventitious bursae,"[79] accumulation of inflamed, fluid-filled, saclike structures between tendon and bone. It has been long-established by scientific preference testing studies that pigs prefer earthen floors over concrete.[80,81]

Gestation Crate Confinement

Pregnant sows are commonly confined to gestation crates,[†] small cages that typically measure 0.6 m (2 ft) wide by 2.13 m (7 ft) long.[82,83] Gestation crates restrict normal postural adjustments and are so narrow that they prevent the sow from even turning around.[84,85]

Gestation crate confinement negatively affects the health and welfare of breeding sows. The restriction of movement and lack of exercise can lead to a reduction in muscle weight and bone strength, making the most basic movements difficult and increasing the probability that the sow will slip and incur physical damage.[86] These restricted animals also have higher basal heart rates, suggesting they are less fit than sows allowed to exercise.[87] They can experience soreness and injuries from rubbing against the bars of their enclosures and from standing or lying on barren flooring,[88] and have a higher rate of urinary tract infections,[89] due to their inactivity, decreased water consumption, and infrequency of urination.[90]

Crated sows also suffer from psychological problems, as evidenced by abnormal behavior. Stereotypies are repetitive behavioral patterns induced by repeated coping attempts, frustration, and/or brain dysfunction,[91] and they are common in captive animals confined in barren or restrictive conditions.[92] Common stereotypies of crated sows include bar-biting (on the crate that confines them) and sham-chewing (with nothing in their mouth).[93] In addition, crated sows tend to become unresponsive over time,[94,95] a behavioral disorder scientists have linked to depression.[96]

Fortunately, public and corporate policy changes are beginning to occur around the globe. Gestation crates were first banned in Sweden and the United Kingdom,[97] and as of January 1, 2013, they are now illegal throughout the entire European Union after four weeks of pregnancy.[98] However, six countries are not yet compliant, which may result in some of them being referred to the European Court of Justice.[99] In 2010, New Zealand passed a ban on gestation crates,[100] and starting in 2017, Tasmania will limit the amount of time a sow can be confined in a gestation crate to 10 days.[101] In 2010, the pork industry initiated a voluntary phase out in the whole of Australia, to be implemented by 2017.[102,103] The South African Pork Producers Association will impose limits on the amount of time a sow can be in a gestation crate to 63 days, a requirement set to go into effect by 2020.[104,105] Nine U.S. states have now enacted legislative bans,[106] and more are being considered.[107]

In 2007, Smithfield Foods, the world's and United States' largest pig producer,[108,109] and Maple Leaf Foods, Canada's largest pig producer,[110] made corporate commitments to phase out their use of gestation crates by 2017.[111,112,113] In 2013, Smithfield announced that nearly 40% of sows in its U.S. company-owned farms were group housed, and their international hog-production operations in Poland and Romania are already using group housing, while Granjas Carroll de Mexico and Norson joint ventures in Mexico are expected to complete the transition by 2022.[114] In 2014, Smithfield announced that it is also asking its U.S. contract farmers to convert to sow group housing by 2022,[115] and the world's largest McDonald's franchisee, Arcos Dorados, announced it will be requiring its pork suppliers to present plans within two years to limit gestation crate use.[116]

Poor Air Quality

Odors, dust, and noxious gases, including ammonia, hydrogen sulfide, and methane, emanate from industrial confinement farming operations due to decomposing animal waste.[117,118] Prolonged ammonia exposure above 35ppm has been found to cause a physiological immune response in pigs, including increases in monocyte, lymphocyte, and neutrophil cell counts.[119] Although a maximum concentration of 25 ppm is recommended for safety,[120] in pig production buildings with poor environmental control, ammonia concentrations may exceed 30 ppm.[121] Studies have shown that juvenile pigs can detect and will avoid atmospheres that contain ammonia, even

[†] For more information, see "An HSUS Report: Welfare Issues with Gestation Crates for Pregnant Sows" at www.humanesociety.org/assets/pdfs/farm/HSUS-Report-on-Gestation-Crates-for-Pregnant-Sows.pdf.

at concentrations as low as 10 ppm, and that they prefer fresh air.[122,123,124] High ammonia concentrations are known to suppress pigs' activity levels.[125]
Poor air quality is also caused by dust. Dust in pig production facilities is biologically active and distinct from ordinary dust, such as field dust, because it contains hazardous agents such as fungi, endotoxins, and bacteria. Sources of dust include feed particles, dander, and fecal material.[126] When fecal material dries, the fine, aerosolized dust particles become inhalable.[127] Dust and gases in pig confinement operations can have serious consequences for the health of people and pigs, including pulmonary disease of workers,[128,129] and pneumonia, pleuritis, and increased neonatal mortality of pigs.[130]

High concentrations of ammonia and dust can reduce the ability of pigs to resist bacterial infections, including infectious atrophic rhinitis. This disease of pigs is caused by bacterial infection of the upper respiratory tract and is characterized by severe and persistent inflammation of the nose that can cause distortion of the nasal bones and, in severe cases, can lead to facial deformity. Atrophic rhinitis is more severe when pigs are raised in environments with high concentrations of dust and ammonia.[131] Poor air quality may also lead to other diseases, including enzootic pneumonia, porcine reproductive and respiratory syndrome (PRRS), and swine influenza.[132] For growing pigs, the majority of deaths are due to respiratory problems.[133]

Lack of Individual Care

New technologies and increased mechanization, such as automated feeders and waterers, coupled with economic pressure to decrease the amount of time staff spend on each animal,[134] have reduced the amount of labor used to operate animal production facilities such that fewer workers now tend to more animals. As such, individualized attention to each animal is generally lacking.[135,136] Indeed, with the use of efficiencies in pen and barn design, one person may be responsible for the care of 8,000 pigs per day.[137]

On both large and small farms, workers can become desensitized to animal suffering, particularly if they are overworked or accustomed to the regular presence of sick and dying animals. Conflicting labor demands can compete for employees' attention and, depending on the level of priority assigned to caring for compromised animals, sick and injured individuals may go untended.[138]

Selective Breeding Problems

Breeding programs for pigs focus heavily on production traits, such as growth rate, feed conversion efficiency, and carcass leanness.[139] Although market weight is typically 113-118 kg (240-270 lb),[140] by keeping pigs longer and selecting for lean weight gain, the industry is moving toward heavier slaughter weights, averaging closer to 136 kg (300 lb).[141] Beginning in the 1990s, "ultralean hybrid" pigs became more common.[142]

Selectively breeding pigs for rapid growth and leanness has led to behavioral and health problems. Porcine stress syndrome (PSS) is an unintentional consequence of genetic selection within the industry for rapid growth of a lean, muscular carcass.[143,144,145] Pigs who have the specific genetic condition associated with PSS are highly sensitive to stress. Affected pigs may exhibit dyspnoea (difficulty breathing), cyanosis (discoloration of the skin), and have elevated body temperature when they become stressed during handling and transportation.[146] These pigs can suffer heart attacks when they become excited[147] and are at a much higher risk of mortality.[148,149] It has also been observed that very lean hybrid pigs are much more excitable and reactive, and more likely to balk, which causes handling problems when they are moved and transported for slaughter.[150] Selection for leanness may have also predisposed certain pig breeds to abnormal tail-biting behavior.[151,152]

Unnatural Feed

Pigs' stomachs are biologically designed for small amounts of high fiber feedstuffs.[153] However, in industrial confinement production, pigs have little access to roughage.[154] Finely ground or pelleted, low fiber diets can cause gastrointestinal acidity and mucosal damage,[155] leaving pigs prone to gastric ulcers.[156,157,158] The incidence

is highly variable, but veterinarians report that the number of cases has increased with the intensification of pig production and may be due in part to the associated stresses of confinement, crowding, the emphasis on feed efficiency and digestibility, and thus the use of finely ground rations.[159,160] Reports vary widely, with incidence between operations ranging from 0-60% of pigs showing distinct signs of ulceration.[161,162,163,164] In one study of the effect of finely ground feeds on ulcer incidence, 53% of pigs already had signs of ulceration and five pigs had bleeding ulcers before the experiment even started, when pigs were just 30 kg (66 lb).[165] In severe cases, pigs may suffer from gastric hemorrhage, bleeding into the stomach, and sudden death.[166,167] The industrial production systems in which most pigs are kept seems to have a large impact on the incidence of these ulcers, as pigs with access to straw, sawdust, or outdoor paddocks have fewer ulcers than those confined on bare, solid or slatted concrete floors.[168,169,170,171]

Growing/finishing pigs in the United States are fed *ad libitum* and reach market weight at an earlier age than those in Europe, where pigs are fed a more limited grain ration. This unrestricted access to feed for pigs who are genetically selected for weight gain is a welfare concern, as it has been implicated as a possible reason that pig mortality rates are higher in the United States compared to some European countries.[172] The welfare conundrum created by this situation could be addressed by reducing emphasis on weight gain in breeding programs.

Feed Additives

Feed additives are routinely added for many reasons, including increased growth rate and improved feed utilization. There are many different classes of feed additives, such as anthelmintics (dewormers), zinc oxide, copper compounds, and probiotics. Pigs are also fed antibiotics and other drugs. The use of antibiotics may improve the welfare of pigs in industrial production, because they can reduce morbidity and mortality,[173] but nontherapeutic use can mask management issues.[174] Further, the agricultural use of important classes of antibiotics used in human medicine may lead to the emergence of antibiotic-resistant pathogens such as *Campylobacter*, *Salmonella*, *E. coli*, and methicillin-resistant *Staphylococcus aureus* (MRSA).[‡]

Recombinant bovine somatotrophin, rBST (also referred to as bovine growth hormone), is a genetically engineered hormone injected into dairy cows to increase milk yield.[175] Unlike cattle in the dairy industry, it is not economically feasible to regularly administer injectable growth hormones to pigs.[176] However, finishing pigs may receive ractopamine—a drug belonging to a class of compounds structurally resembling epinephrine (adrenaline) and norepinephrine, which are naturally occurring hormones—as a feed additive.[177]

Emerging research from Purdue University has demonstrated that ractopamine use is concerning from an animal welfare standpoint.[178,179,180] Ractopamine is a beta agonist; its metabolic effect is to repartition nutrients away from fat, moving them instead toward lean tissue. It is also used because it mobilizes body fat, improves feed efficiency, increases growth rate, and results in a leaner carcass.[181] In a series of studies, pigs "finished" with ractopamine have shown increased impulsive aggression,[182] more abnormal behavior,[183] and difficulty walking.[184] In the first study, published in 2003, pigs finished with ractopamine had elevated heart rates and catecholamine concentrations, were initially more active and more difficult to handle, and had increased stress reactions in response to transportation. These animals showed a marked increase in the number of pats, slaps, and pushes stockpersons used on them because they were difficult to move. The scientists stated that reluctance to move may leave pigs more likely to be subjected to rough handling during loading and unloading, for example.[185] Observations at slaughter plants corroborate the additional finding that difficulty walking due to ractopamine may contribute to a greater incidence of nonambulatory (or "downed") pigs, those too weak to stand and walk on their own accord.[186,187] Additionally, a 2009 publication reported that pigs fed ractopamine had a greater frequency of front and rear hoof lesions.[188]

[‡] For more information see "An HSUS Report: Human Health Implications of Non-Therapeutic Antibiotic Use in Animal Agriculture" at www.hsus.org/web-files/PDF/farm/HSUS-Human-Health-Report-on-Antibiotics-in-Animal-Agriculture.pdf.

Inhumane Handling

In commercial pig confinement operations, the animals are largely unaccustomed to novel experiences and unfamiliar places, so moving them between production sites or onto a transport truck can be difficult for both pigs and handlers. If the pigs have not previously experienced regular, gentle human handling, they may fear people and become flighty and nervous when they come into human contact.[189,190]

Apprehensive pigs entering a new environment may be reluctant to move, especially given the physical exertion that may be required to navigate alleyways, ramps, and truck interiors. There are many different tools available as driving aids, but handlers often make excessive use of electric prods (or goads),[191] a device that delivers a high voltage electric shock. These are more commonly used in poorly designed facilities or by stockpersons with little training in animal handling. Despite industry-wide recognition that electric prods are stressful for pigs, their use remains widespread.[192]

A more humane device for herding pigs forward is the sorting board, a large, rectangular plank slightly narrower than the width of the aisle through which pigs must walk. The handler stands behind the board, holding it by grips on each side, and walks forward, encouraging the pigs to move without use of force, electric prodding, or other more aversive means.[193] Although use of the sorting board is thought to achieve higher welfare, at least one study found no difference in heart rate (a measure of stress) among groups of pigs moved with a variety of tools, including an electric prod and sorting board.[194]

Scientists studying the transport of pigs have observed that as handling crews become fatigued after loading several trailers with pigs, they may become more aggressive in their attempts to move the animals. This has been proposed as an explanation as to why the number of nonambulatory pigs identified on-farm during loading for transport is positively correlated with the load number of the day.[195]

On-Farm Killing

When animals become sick or injured and their pain and suffering cannot be controlled, or if producers do not deem treatment to be cost-effective, the pigs are sometimes killed on-farm.[196] Euthanasia is defined as killing an animal in a humane way for his/her own benefit.[197,198] Achieving true euthanasia—i.e., killing the animals in a humane way in order to end their suffering—can be challenging. Acceptable methods, according to the National Pork Board and the American Association of Swine Veterinarians, include gunshot, penetrating captive bolt gun, anesthetic overdose, and electrocution.[199] In one highly publicized incident, however, an undercover investigator videotaped an Ohio producer killing sick pigs by hanging, lifting them by a chain around their neck using a forklift.[200] This is certainly not euthanasia or humane killing. Killing is not always performed in a timely manner, and pigs who should be killed are sometimes left to languish, over the weekend for example, depending on staff availability and the facility schedule.[201]

Transport

Young pigs may be transported from farrowing operations to grow-out facilities for feeding[202] during the growing and finishing stages of production. When pigs reach market weight, they are transported from the finishing facility to the slaughter plant. Loading onto a truck, the subsequent journey, and unloading are stressful[203] and sometimes traumatic[204] events. Although conditions for each trip vary, pigs can experience a range of stressors, including potentially rough handling, unfamiliar surroundings, frightening situations, social stress (e.g., regrouping with unfamiliar individuals, which may lead to fighting),[205] crowding, temperature extremes, changes in acceleration, and vibration due to motion.[206,207,208]

Before the journey begins, the welfare of pigs may be poor during handling and loading. Long loading distances from the finishing shed to the transport trailer can lead to physical indicators of stress, such as open-mouth breathing and skin discoloration.[209] Climbing a loading ramp is more difficult for pigs compared to other farmed

animals.[210] Steeper ramps cause an elevation in heart rate[211] and require more time to climb.[212] Pigs may become injured or bruised as they are loaded due to fighting among newly mixed pigs or abrasion from forceful contact with the walls of enclosures.[213,214] If pigs are loaded too quickly, there is a greater chance of subsequent mortality, an outcome that scientists have postulated may be a consequence of poor animal handling.[215]

Feed and water may be limited or withheld for 16-24 hours in preparation for transport of pigs to slaughter.[216] This practice is observed for many reasons, including to prevent pigs from vomiting due to motion sickness, to reduce the risk of puncturing the intestines during evisceration, because pigs who have full stomachs are more likely to die during transport,[217,218,219] and to reduce feed costs as the final feeding will not be assimilated prior to slaughter.[220] As a result, pigs experience hunger, dehydration, and accompanying stress and fatigue in response to nutrient withdrawal.[221]

During the journey, the comfort and postural stability of animals may be affected by the driver. Sudden breaking and acceleration, as well as turning rapidly, can cause animals to experience horizontal load forces of 20-33% of their own body weight, stress, and possible injury due to falls.[222] Pigs may experience motion sickness during the journey and retch while the truck is in motion.[223,224,225]

Transport may cause so much stress that animals experience physiological consequences that manifest in meat quality changes, an important economic concern to industry. Pigs in transport are prone to glycogen depletion of muscle, which is associated with fatigue, and a condition industry terms "dark, firm, and dry" (DFD) meat.[226] Rapid muscle acidification associated with pre-slaughter stress can lead to "pale, soft and exudative" (PSE) meat.[227,228]

Genetic differences may predispose pigs from certain breeding lineages to become more excitable during handling.[229] Pigs with porcine stress syndrome have increased stress susceptibility, often producing PSE meat.[230] They are also at a greater risk of experiencing severe distress and death during transport.[231,232] However, advances in technologies capable of identifying and eliminating the gene responsible for extreme cases of PSE are thought to have greatly reduced the incidence and severity.[233]

The temperature both outside and inside the truck trailer can affect the comfort and welfare of pigs during transport. Compared to the ambient temperature outside, temperatures inside the trailer will generally increase during loading, while the truck is not moving, and decrease when the vehicle is in motion.[234]

Pigs are susceptible to heat stress.[235] They are particularly intolerant to heat because they lack functioning sweat glands. Pigs naturally use behavioral means to cool themselves, such as wallowing in mud, if allowed to do so, but when confined to a transport vehicle, they are unable to thermoregulate behaviorally. Compounding these factors are the effects of transport stress, which can alter heat production, and dehydration due to lack of water.[236]

Studies of typical ambient conditions in North America as they relate to pig welfare during transport are limited.[237] Although a 2005 study replicated over several seasons found no correlation between trailer temperature and mortality, when average trailer temperature varied between 2.6-24.0°C (36.7-75.2°F),[238,239] studies in other countries have demonstrated that warm environmental conditions can be dangerous to animals. Published in 1994, a major survey of pig transport in England found that the effect of heat was detrimental, with a substantially higher mortality when pigs were moved while outside temperatures were above 15-17 0°C (59-62.6°F).[240] A 2008 survey of 739 journeys to 37 different slaughter plants in 5 European countries found that the risk of mortality increased as the average temperature during transport rose to the highest temperature recorded in the study, 39°C (102.2°F).[241] High temperatures[242] and summer transport[243] can also increase the occurrence of PSE meat. These problems can often be avoided by transporting the animals at night when temperatures are lower.

Humidity can lower the temperature at which animals will begin to experience heat stress, because it limits evaporative heat loss,[244] effectively amplifying the effects of high temperature. A 2008 study noted that "total

losses" (including dead and nonambulatory animals) increase with the temperature-humidity index as well as with the stocking density of the transport trailer.[245]

Extremely cold conditions are also detrimental. Higher incidences of DFD carcasses[246] and nonambulatory pigs have been found in winter months.[247] Wind chill causes the temperature in a moving truck to drop considerably below the outside ambient temperature. If pigs become wet due to freezing rain, the situation can become fatal.[248]

While many journeys are short (less than 300 miles),[249] animals used for agricultural purposes are increasingly being transported over longer distances[250] due to movement of young pigs across state lines for feeding in the Midwest[251] and to concentration of the slaughtering industry into fewer, larger plants.[252] There is concern that a disease causing organism could potentially travel thousands of miles between farrowing and finishing before infected pigs would be discovered.[253,254] Fatigue from long-distance transport takes a physical toll. Longer transport times are associated with a greater risk of DFD meat[255] and are correlated with the number of dead-on-arrival (DOA) pigs.[256,257] This may be particularly relevant if the long journey is undertaken in warmer temperatures, in excess of 15°C (59°F).[258]

Upon arrival at the slaughter facility, some pigs are too sick, injured, stressed, or fatigued to walk on their own accord. Others do not survive the trip. Estimates of the number of DOA pigs in the United States range from 0.23-0.25%.[259,260] Scientists have suggested that about 1% of all transported pigs arrive at slaughter plants either dead or nonambulatory due to injury, fatigue, or illness,[261] an approximate figure that was corroborated in a 2008 study of more than 12,000 trailer loads of pigs transported to a slaughter plant in Iowa. This study found that a total of 0.85% of pigs arrived nonambulatory (0.60%) or dead (0.25%).[262] If the trailer loads in this study are representative of other pigs in U.S. transport, then of the 113.6 million pigs slaughtered in the United States in 2009,[263] over 681,000 pigs arrived nonambulatory and 284,000 arrived dead at slaughter facilities.

A number of interacting factors are thought to cause these deaths during transport, including environmental conditions, loading distances at the farm, specific handlers and drivers, and waiting times at the slaughter plant.[264] Pigs who have died during transport often show cardiac dilation, possibly from cardiac failure associated with stress.[265] Because the mortality rate is partially determined by transport conditions, it is an indicator of welfare for all pigs on the trip, even those who survive.[266]

Downed Pigs

Pigs may become nonambulatory if they are too sick or injured to stand and walk on their own accord, but many also become downed without obvious signs of illness or physical trauma, and these downed pigs are said to suffer from "fatigued pig syndrome."[267,268] The welfare of downed pigs is a serious concern, and their treatment and handling are critical.

A 2008 study found that nonambulatory pigs can be affected by a number of different health problems, and the prevalence of these problems may differ amongst slaughter plants. Conditions affecting downed pigs include ascarid (worm) infection, respiratory disease, liver damage, ulcers, subtle bone injury, and feet and leg problems. One factor or a combination may be involved. Changes in leukocyte percentages and albumin concentrations suggest that nonambulatory, non-injured pigs often suffer from active infections, and higher creatinine and blood urea nitrogen (BUN) concentrations are possibly due to kidney dysfunction. Both factors may contribute to pigs becoming nonambulatory during transport.[269]

In the same study, downed pigs were also found to have higher aspartate aminotransferase (AST) and alkaline phosphatase (ALP) concentrations. AST is an enzyme of the liver that is released into the bloodstream when the heart or liver is injured. ALP, also an enzyme, is found in the intestines, liver, bone, and kidneys. When these organs are damaged, ALP may leak into the blood. The increased AST and ALP concentrations may indicate damage to the liver or bone, and the study scientists suggest that this could be due to "slight bone injuries or fractures."[270]

There are a variety of factors that increase the risk of a pig becoming a downer. The trend toward raising the animals to heavier final body weight has been implicated as one likely cause.[271] Older sows are also more likely to become nonambulatory, due to the metabolic demand of lactation and traumatic or infectious arthritides.[272] The time pigs spend on the truck at the production facility and the unloading time at the slaughter plant are also important factors affecting their mobility.[273]

In a 2005 study of 74 trailer loads of pigs from two different finishing sites in the United States, 0.26% of pigs were found to be nonambulatory at the farm and 0.85% were nonambulatory by arrival at the slaughter plant. Of the 74 loads, 65 were further evaluated at the plant, and it was determined that 0.24% of pigs in those loads were nonambulatory due to injury and 0.55% were downed but not injured.[274,275] In another study, scientists estimated that the rate of fatigued pig syndrome is 0.3% of all pigs transported.[276] A 2008 study reported the incidence of "fatigued" pigs at 0.55% and the incidence of injured pigs at 0.05% per trailer.[277]

Slaughter

Following lairage at the slaughter plant, the pigs are moved through a series of chutes into position for stunning. Pigs are sometimes rendered insensible prior to slaughter with the use of a captive bolt gun, an electric current, or by carbon dioxide (CO_2) gassing. A captive bolt gun fires a steel bolt powered by gun powder or compressed air into the forehead of the pig, causing concussion.[278,279] If an electrical method is used, current is applied using stunning electrodes (tongs) placed on both sides of the head, so that the current runs through the brain.[280] In plants where CO_2 stunning is used, groups of pigs are lowered into a gas-filled chamber until they become unconscious.[281] After being rendered insensible using one of these methods, the pig is shackled and hoisted by a hind leg. The pig is "stuck" with a knife, just below the point of the breast bone, severing arteries and veins, and the pig then dies from exsanguination (blood loss). The pig's body is then conveyed to a scalding vat, where 65.6°C (150°F) water loosens the hair in preparation for processing of the carcass.[282] All stunning methods depend on good equipment maintenance, personnel training, and proper use to be effective to full potential.[283,284]

The adequacy of stunning methods at producing unconsciousness (and insensibility) has been elucidated in laboratory studies using electroencephalogram (EEG) recordings and other neurological measures. Studies using cattle and sheep have demonstrated that the captive bolt gun is capable of producing an immediate, unequivocal stun based on electrical activity recorded in the brain.[285,286,287] When correct amplitude, frequency, and wave form is used, electrical stunning is also effective—EEG recordings show epileptiform activity,[288] a state associated with unconsciousness in humans.[289,290] CO_2 stunning, however, is not instantaneous, and neurological measures in a 2008 study reported that it took 60 seconds for pigs to become unconscious when lowered into a pit under commercially simulated conditions in the laboratory.[291] CO_2 is an acidic, pungent gas[292,293] that can induce severe respiratory distress.[294,295] As such, its use is thought to be aversive to pigs at high concentrations and is questionable on animal welfare grounds. The inert gas argon does not lead to the period of poor welfare before death that occurs when carbon dioxide is used for stunning. Gas stunning in well designed conditions allows better handling of animals and improves pre-stun welfare compared to electrical stunning.[296]

Immediately after an animal is rendered unconscious or is stuck, vigorous convulsions may occur.[297,298] Unconscious pigs may kick while hanging on the line, which can be misinterpreted as an ineffective stun.[299] Convulsions may occur because higher brain centers that have been rendered dysfunctional are no longer able to inhibit spinal reflexes.[300] Neurological recordings confirm that animals are unconscious if properly stunned.[301,302] However, it is not completely clear whether muscular movements that occur during CO2 stunning are reflexive, convulsive activity of unconscious animals, or if they are conscious attempts to avoid the gas. Some studies conclude the former,[303,304,305] while others find the latter may be true.[306,307,308]

Conclusion

Most pigs are now raised on industrial confinement operations, massive agribusinesses where animal welfare concerns often remain unaddressed despite substantial scientific evidence that pigs in these conditions routinely suffer in a variety of ways. Low levels of environmental stimulation in barren surroundings, the lack of opportunity to express key natural behavior, such as rooting, wallowing, exploring, and nesting, and the inability to separate into natural social groups may lead to boredom, frustration, and aggression. Behavioral abnormalities and health problems are common, and pigs may not receive the individualized care they need. Improved on-farm killing methods for sick or injured animals who are suffering and unlikely to recover are desperately needed. Genetic selection programs and feed additives push the animals to their biological limit, and although most may be able to endure stressful handling and transportation, some pigs do not survive the journey or become so weak, injured, stressed, or ill that they become nonambulatory. The pig production industry has failed to fully recognize and adequately address these welfare concerns.

Improving the welfare of pigs does not necessarily mean returning to historic farming methods. Rather, it involves using science and technology to develop the best aspects of all of the techniques available to date for the betterment of the animals' welfare, and moving forward, to develop systems that enable the pigs to reach even higher levels of welfare. For example, the Food Animal Initiative (FAI), an experimental farm associated with Oxford University in the United Kingdom is testing new ideas and reexamining pre-confinement practices. In its program for pigs, FAI is perfecting new systems with animal welfare as a core principle, incorporating environmental enrichment and greater freedom of movement into new, commercially viable production methodology.[309] However, the philosophy behind programs such as the FAI has not yet been embraced by industry.

Improvements in welfare will depend upon not only employment of new ways of farming, but also on a new way of viewing farmed animals. Pigs have been commodified and treated simply as units of production. Individuals who do not grow large enough or fast enough are referred to as "junk pigs" in the trade literature,[310] rather than as the sentient beings they are. Such attitudes undoubtedly impair advances in ethical decision-making about the pigs' welfare on industrial production operations. Pigs are among the most intensively confined and harshly handled species in animal agriculture, and there is a desperate need to raise the bar for their housing, care, and treatment throughout the industry.

---

[1] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 4).
[2] Graves HB. 1984. Behavior and ecology of wild and feral swine (*Sus scrofa*). Journal of Animal Science 58(2):482-492.
[3] Stolba A and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. Animal Production 48:419-25.
[4] Jensen P. 2002. The Ethology of Domestic Animals: An Introductory Text (Wallingford, U.K.: CABI Publishing, p. 162).
[5] Jensen P. 2002. The Ethology of Domestic Animals: An Introductory Text (Wallingford, U.K.: CABI Publishing, p. 162).
[6] Graves HB. 1984. Behavior and ecology of wild and feral swine (*Sus scrofa*). Journal of Animal Science 58(2):482-492.
[7]Schmidt CR. 1990. Grzimek's Encyclopedia of Mammals, volume 5 (New York, NY: McGraw-Hill Publishing Company, p. 47).
[8] Pew Commission on Industrial Farm Animal Production. 2008. Putting Meat on the Table: Industrial Farm Animal Production in America. http://www.ncifap.org/_images/PCIFAPFin.pdf. Accessed February 21, 2010.
[9] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 388).
[10] Deyoe GP and Krider JL. 1952. Raising Swine (New York: McGraw-Hill Book Company, Inc., pp. 195-206).
[11] Anderson AL. 1957. Swine Management, 2nd Edition (Chicago, IL: J.B. Lippincott Company, p. 226).
[12] Anderson AL. 1957. Swine Management, 2nd Edition (Chicago, IL: J.B. Lippincott Company, p. 110).
[13] Price EO. 1984. Behavioral aspects of animal domestication. The Quarterly Review of Biology 59(1):1-32.

[14] Stolba A, and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. Animal Production 48:419-25.
[15] MacDonald JM and McBride W. 2009. The transformation of U.S. livestock agriculture: scale, efficiency, and risks. U.S. Department of Agriculture, Economic Research Service, bulletin 43. www.ers.usda.gov/Publications/EIB43/. Accessed February 21, 2010.
[16] U.S. Department of Agriculture. 2008. Part IV: Changes in the U.S. Pork Industry, 1990-2006 USDA:APHIS:VS National Animal Health Monitoring System. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/swine2006/Swine2006_PartIV.pdf. Accessed May 5, 2010.
[17] MacDonald JM and McBride W. 2009. The transformation of U.S. livestock agriculture: scale, efficiency, and risks. U.S. Department of Agriculture, Economic Research Service, bulletin 43. www.ers.usda.gov/Publications/EIB43/. Accessed February 21, 2010.
[18] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Delmar Learning, p. 16).
[19] Freese B. 2006. Pork powerhouses 2006. Successful Farming, October. www.agriculture.com/ag/pdf/06PorkPowerhouses.pdf. Accessed February 21, 2010.
[20] Smithfield Foods. Understanding Smithfield: History of Smithfield Foods. www.r-calfusa.com/industry_info/2008_JBS_merger/Exhibit18_HistoryofSmithfieldFoods.pdf. Accessed February 21, 2010.
[21] Freese B. 2013. Top 25 U.S. Pork Powerhouses 2013. Successful Farming, October. http://www.agriculture.com/uploads/assets/promo/external/pdf/PP2013_03.pdf. Accessed April 22, 2014.
[22] Food and Agriculture Organization of the United Nations. 2014. FAOSTAT Statistical Database. http://faostat.fao.org. Accessed April 22, 2014.
[23] Food and Agriculture Organization of the United Nations, Commission on Genetic Resources for Food and Agriculture. 2007. The state of the world's animal genetic resources for food and agriculture. www.fao.org/docrep/010/a1250e/a1250e00.htm. Accessed January 10, 2011.
[24] Verge XPC, De Kimpe C, and Desjardins RL. 2007. Agricultural production, greenhouse gas emissions and mitigation potential. Agricultural and Forest Meteorology 142:255-69.
[25] Food and Agriculture Organization of the United Nations. 2009. The state of food and agriculture: livestock in the balance, p. 27. www.fao.org/docrep/012/i0680e/i0680e.pdf. Accessed January 10, 2011.
[26] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, New Jersey: Pearson Prentice Hall, pp. 359, 366).
[27] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 388, 440).
[28] Blackwell T. 2004. Production practices and well-being: swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, Iowa: Blackwell Publishing, pp. 241-69).
[29] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 388, 440).
[30] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Thompson Delmar Learning, p. 20).
[31] Kurz JC and Marchinton RL. 1972. Radiotelemetry studies of feral hogs in South Carolina. Journal of Wildlife Management 36(4): 1240-8.
[32] Stolba A, and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. Animal Production 48:419-25.
[33] U.S. Department of Agriculture National Agricultural Statistics Service. 2006. Swine 2006 part III: reference of swine health, productivity, and general management in the United States, p. 25. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/swine2006/Swine2006_PartIII.pdf. Accessed February 21, 2010.
[34] Kurz JC and Marchinton RL. 1972. Radiotelemetry studies of feral hogs in South Carolina. Journal of Wildlife Management 36(4): 1240-8.
[35] Graves HB. 1984. Behavior and ecology of wild and feral swine (*sus scrofa*). Journal of Animal Science 58(2):482-492.

[36] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Thompson Delmar Learning, p. 254).
[37] Fitzgerald RF, Stalder KJ, Matthews JO, Schultz Kaster CM, and Johnson AK. 2009. Factors associated with fatigued, injured, and dead pig frequency during transport and lairage at a commercial abattoir. Journal of Animal Science 87:1156-66.
[38] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Thompson Delmar Learning, p. 254).
[39] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 361).
[40] Stolba A and Wood-Gush DGM. 1984. The identification of behavioural key features and their incorporation into a housing design for pigs. Annales de Recherches Vétérinaires 15(2):287-98.
[41] Blackwell TE. 2004. Production practices and well-being: Swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, Iowa: Blackwell Publishing, pp. 241-69).
[42] Jensen P and Wood-Gush GM. 1984. Social interactions in a group of free-ranging sows. Applied Animal Behaviour Science 12:327-337.
[43] Stolba A and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. Animal Production 48:419-25.
[44] Jensen P and Wood-Gush DGM. 1984. Social interactions in a group of free-ranging sows. Applied Animal Behaviour Science 12:327-337.
[45] Sørensen V, Jorsal SE, and Mousing J. Diseases of the respiratory system. In: Straw BE, Zimmerman JJ, D'Allaire S, and Taylor DJ (eds.), Diseases of Swine, 9th Edition (Ames, Iowa: Blackwell Publishing, pp.149-78).
[46] Blackwell TE. 2004. Production practices and well-being: Swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, Iowa: Blackwell Publishing, pp. 241-69).
[47] Sørensen V, Jorsal SE, and Mousing J. 2006. Diseases of the respiratory system. In: Straw BE, Zimmerman JJ, D'Allaire S, and Taylor DJ (eds.), Diseases of Swine, 9th Edition (Ames, Iowa: Blackwell Publishing, pp.149-78).
[48] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, New Jersey: Pearson Prentice Hall, p. 4).
[49] Fraser AF. 1980. Farm Animal Behaviour (London, Great Britain: Bailliére Tindall, p.181).
[50] Stolba A, and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. Animal Production 48:419-25.
[51] Beattie VE, O'Connell NE, and Moss BW. 2000. Influence of environmental enrichment on the behaviour, performance and meat quality of domestic pigs. Livestock Production Science 65:71-9.
[52] Beattie VE, Walker N, and Sneddon IA. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. Animal Welfare 4:207-20.
[53] Broom DM. 1987. Applications of neurobiological studies to farm animal welfare. In: Wiepkema PR and van Adrichem PWM (eds.), Biology of Stress in Farm Animals: an Integrated Approach. Current Topics in Veterinary Medicine. Animal Science 42:101-10 (Dordrecht: Martinus Nijhoff).
[54] Broom DM. 1989. The assessment of sow welfare. Pig Veterinary Journal 22:100-11.
[55] Wood-Gush DGM and Beilharz RG. 1983. The enrichment of a bare environment for animals in confined conditions. Applied Animal Ethology 10:209-17.
[56] Wemelsfelder F and Birke L. 1997. Environmental challenge. In: Appleby MC and Hughes BO (eds.), Animal Welfare (Wallingford, U.K.: CABI Publishing, pp. 35-47).
[57] Wood-Gush DGM and Vestergaard K. 1989. Exploratory behavior and the welfare of intensively kept animals. Journal of Agricultural Ethics 2:161-9.
[58] Smulders D, Hautekiet V, Verbeke G, and Geers R. 2008. Tail and ear biting lesions in pigs: an epidemiological study. Animal Welfare 17:61-9.
[59] Blackshaw JK. 1981. Some behavioural deviations in weaned domestic pigs: persistent inguinal nose thrusting, and tail and ear biting. Animal Production 33:325-32.
[60] Gregory NG. 2007. Animal Welfare and Meat Production, 2nd Edition (Wallingford, U.K.: CABI, p. 108-9).

[61] Scientific Veterinary Committee, European Commission. 1997. The welfare of intensively kept pigs. Adopted September 30, 1997. http://ec.europa.eu/food/fs/sc/oldcomm4/out17_en.pdf. Accessed February 21, 2010.
[62] Kritas SK and Morrison RB. 2007. Relationships between tail biting in pigs and disease lesions and condemnations at slaughter. Veterinary Record 160:149-52.
[63] Blackshaw JK. 1981. Some behavioural deviations in weaned domestic pigs: persistent inguinal nose thrusting, and tail and ear biting. Animal Production 33:325-32.
[64] Goossens X, Sobry L, Ödberg F, et al. 2008. A population-based on-farm evaluation protocol for comparing the welfare of pigs between farms. Animal Welfare 17:35-41.
[65] Beattie VE, Walker N, and Sneddon IA. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. Animal Welfare 4:207-20.
[66] Beattie VE, Sneddon IA, Walker N, and Weatherup RN. 2001. Environmental enrichment of intensive pig housing using spent mushroom compost. Animal Science 72(1):35-42.
[67] Scott K, Chennells DJ, Campbell FM, et al. 2006. The welfare of finishing pigs in two contrasting housing systems: fully-slatted versus straw-bedded accommodation. Livestock Science 103:104-15.
[68] Cagienard A, Regula G, and Danuser J. 2005. The impact of different housing systems on health and welfare of grower and finisher pigs in Switzerland. Preventive Veterinary Medicine 68:49–61.
[69] Scientific Veterinary Committee, European Commission. 1997. The Welfare of Intensively Kept Pigs. Adopted September 30, 1997, p.39. http://ec.europa.eu/food/animal/welfare/farm/out17_en.pdf. Accessed February 21, 2010.
[70] Weerd HA van de, Docking CM, Day JEL, and Edwards SE. 2005. The development of harmful social behaviour in pigs with intact tails and different enrichment backgrounds in two housing systems. Animal Science 80(3):289-98.
[71] Day JEL, Weerd HA van de, and Edwards SA. 2008. The effect of varying lengths of straw bedding on the behaviour of growing pigs. Applied Animal Behaviour Science 109:249-60.
[72] Guy JH, Rowlinson P, Chadwick JP, and Ellis M. 2002. Behaviour of two genotypes of growing–finishing pig in three different housing systems. Applied Animal Behaviour Science 75:193-206.
[73] Moinard C, Mendl M, Nicol CJ, and Green LE. 2003. A case control study of on-farm risk factors for tail biting in pigs. Applied Animal Behaviour Science 81:333-55.
[74] Blackwell TE. 2004. Production practices and well-being: Swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, Iowa: Blackwell Publishing, pp. 241-69).
[75] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 388-9).
[76] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 375-8).
[77] Bäckström L. 1973. Environment and animal health in piglet production: a field study of incidences and correlations. Acta Veterinaria Scandinavica supplementum 41, p.171-9.
[78] Gregory NG. 2007. Animal Welfare and Meat Production, 2nd Edition (Wallingford, U.K.: CABI, p. 109).
[79] Kilbride AL, Gillman CE, and Green LE. 2008. Prevalence of foot lesions, limb lesions and abnormal locomotion in pigs on commercial farms in Britain and risks associated with flooring. The Pig Journal 61:62-8.
[80] Van Rooijen J. 1982. Operant preference tests with pigs. Applied Animal Ethology 9:87-8.
[81] Beattie VE, Walker N, and Sneddon IA. 1998. Preference testing of substrates by growing pigs. Animal Welfare 7:27-34.
[82] McGlone J. Undated. Alternative sow housing systems: driven by legislation, regulation, free trade and free market systems (but not science). Pork Industry Institute. Texas Tech University. www.depts.ttu.edu/porkindustryinstitute/SowHousing_files/Sow%20housing%20Manitoba.pdf. Accessed August 6, 2009.
[83] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 399).
[84] Marchant JN and Broom DM. 1996. Factors affecting posture-changing in loose-housed and confined gestating sows. Animal Science 63:477-85.
[85]Anil L, Anil SS, and Deen J. 2002. Evaluation of the relationship between injuries and size of gestation stalls relative to size of sows. JAVMA 221(6):834-6.

[86] Marchant JN and Broom DM. 1996. Effects of dry sow housing conditions on muscle weight and bone strength. Animal Science 62:105-13.
[87] Marchant JN, Rudd AR, and Broom DM. 1997. The effects of housing on heart rate of gestating sows during specific behaviours. Applied Animal Behaviour Science 55:67-78.
[88] Anil L, Anil SS, and Deen J. 2002. Evaluation of the relationship between injuries and size of gestation stalls relative to size of sows. Journal of the American Veterinary Medical Association 221(6):834-6.
[89] Scientific Veterinary Committee, European Commission. 1997. The Welfare of Intensively Kept Pigs. Adopted September 30, 1997, p. 96. http://ec.europa.eu/food/fs/sc/oldcomm4/out17_en.pdf. Accessed March 25, 2010.
[90] Tillon JP and Madec F. 1984. Diseases affecting confined sows: data from epidemiological observations. Annales de Recherches Vétérinaires (Annals of Veterinary Research) 15(2):195-9.
[91] Mason G and Rushen J. 2006. Stereotypic Animal Behaviour: Fundamentals and Applications to Welfare, 2nd Edition (Wallingford, U.K.: CABI, p. 347).
[92] Mason GJ and Latham NR. 2004. Can't stop, won't stop: is stereotypy a reliable animal welfare indicator? Animal Welfare13:S57-69.
[93] Bergeron R, Badnell-Waters AJ, Lambton S, and Mason G. 2006. Stereotypic oral behaviour in captive ungulates: foraging, diet and gastrointestinal function. In: Mason G and Rushen J (eds.), Stereotypic Animal Behaviour: Fundamentals and Applications to Welfare, 2nd Edition (Wallingford, U.K.: CABI, pp.19-57).
[94] Broom DM. 1986. Stereotypies and responsiveness as welfare indicators in stall-housed sows. Animal Production 42:438-9.
[95] Barnett JL, Hemsworth PH, Cronin GM, Jongman EC, and Hutson GD. 2001. A review of the welfare issues for sows and piglets in relation to housing. Australian Journal of Agricultural Research 52:1-28, citing: Barnett JL. 1995. The welfare of sows: housing options for dry sows. Report to the Pig Research and Development Corporation. Canberra.
[96] Scientific Veterinary Committee, European Commission. 1997. The Welfare of Intensively Kept Pigs. Adopted September 30, 1997, p. 93. http://ec.europa.eu/food/fs/sc/oldcomm4/out17_en.pdf. Accessed March 25, 2010.
[97] Salley J. 2012. The Crate Debate. Journal Watchdog, May 31. www.journalwatchdog.com/business/1459-the-crate-debate. Accessed February 19, 2014.
[98] Council Directive 2001/88/EC of 23 October 2001 amending Directive 91/630/EEC laying down minimum standards for the protection of pigs. Official Journal of the European Communities L316:1-4. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:316:0001:0004:EN:PDF. Accessed February 19, 2014.
[99] Nuthall, K. 2014. EU increases crackdown on pig stall flouters. Global Meat News, January 27. www.globalmeatnews.com/Industry-Markets/EU-increases-crackdown-on-pig-stall-flouters. Accessed February 13, 2014.
[100] Kloeten, N. 2010. Sow stalls to be banned. The National Business Review, December 1. www.nbr.co.nz/article/sow-stalls-be-banned-134068. Accessed February 13, 2014.
[101] Australian Broadcasting Corporation. 2013. Minister accused of backflip on Tasmanian piggeries. ABC news, August 5. www.abc.net.au/news/2013-08-05/minister-accused-of-backflip-on-sow-stall-ban/4864564. Accessed February 13, 2014.
[102] 2010. Sow stalls gone by 2017. The Stock Journal, November 17. http://sj.farmonline.com.au/news/nationalrural/livestock/news/sow-stalls-gone-by-2017/2000410.aspx. Accessed January 31, 2013.
[103] Smith A. 2012. More piglets 'born free' as producers voluntarily phase out sow stalls. The Sydney Morning Herald, April 16. www.smh.com.au/environment/animals/more-piglets-born-free-as-producers-voluntarily-phase-out-sow-stalls-20120415-1x1n8.html. Accessed January 31, 2013.
[104] South African Pork Producers' Organisation. 2011. Proposed change to SAPPO welfare code on gestation stalls: Interim statement from SAPPO on gestation crates/tethers. Media release, January 28. www.sapork.biz/wp-content/uploads/2011/01/20112.html. Accessed January 31, 2013.

[105] Joubert R. 2012. Renewed pressure on use of gestation crates. Farmer's Weekly, November 11. www.farmersweekly.co.za/news.aspx?id=31205&h=Renewed-pressure-on-use-of-gestation-crates. Accessed February 7, 2013.
[106] Huffstutter, P. 2013. New Jersey governor vetoes ban on gestation crate use. Reuters, June 27. www.reuters.com/article/2013/06/27/us-usa-farm-gestation-crate-veto-idUSBRE95Q1I920130627. Accessed February 14, 2014.
[107]Friedman, M. 2014. NJ Senate committee to take up pig confinement bill again. The Star-Ledger, January 30. www.nj.com/politics/index.ssf/2014/01/nj_senate_committee_to_take_up_pig_confinement_bill_again.html. Accessed January 30, 2014.
[108] Smithfield Foods. Understanding Smithfield: History of Smithfield Foods. www.r-calfusa.com/industry_info/2008_JBS_merger/080409-Exhibit18_HistoryofSmithfieldFoods.pdf. Accessed January 31, 2013.
[109] Successful Farming. 2007. Pork powerhouses 2007. http://images.meredith.com/ag/pdf/2007SFPorkPowerhouses07.pdf. Accessed January 31, 2013.
[110] Successful Farming. 2007. Pork powerhouses 2007. http://images.meredith.com/ag/pdf/2007SFPorkPowerhouses07.pdf. Accessed January 31, 2013.
[111] PRNewswire. 2007. Smithfield Foods Makes Landmark Decision Regarding Animal Management. January 25. www.prnewswire.com/news-releases/smithfield-foods-makes-landmark-decision-regarding-animal-management-53754097.html. Accessed January 31, 2013.
[112] Maple Leaf Foods. 2007. Maple Leaf endorses U.S. industry direction on sow stalls. Press release issued January 31. http://investor.mapleleaf.ca/phoenix.zhtml?c=88490&p=irol-newsArticle&ID=956262&highlight. Accessed January 31, 2013.
[113] LoGiurato B. 2011. McDonald's Pork Supplier Smithfield Farms Reaffirms Commitment to Phase Out Gestation Crates. International Business Times, December 8. www.ibtimes.com/articles/264156/20111208/mcdonalds-mcrib-smithfield-foods-farms-pigs-gestation.htm. Accessed January 31, 2013.
[114] Doherty K. 2013. Smithfield: On track for crate-free sows by '17. Arkansas Democrat-Gazette, January 3. http://m.arkansasonline.com/news/2013/jan/03/smithfield-track-crate-free-sows-17/. Accessed January 30, 2014.
[115] Smithfield Foods, Inc. 2014. Smithfield Foods Recommends Its Contract Growers Convert to Group Housing for Pregnant Sows. Press release issued January 7. http://investors.smithfieldfoods.com/releasedetail.cfm?ReleaseID=817511. Accessed January 31, 2014.
[116] Arcos Dorados Holdings, Inc. 2014. Arcos Dorados is committed to improved animal welfare in pork supply chain. Press release issued April 11, 2014. http://www.arcosdorados.com/attached/news/bienestar-animal_en.docx. Accessed April 22, 2014.
[117] Gregory NG. 2007. Animal Welfare and Meat Production, 2nd Edition (Wallingford, U.K.: CABI, p. 110).
[118] Donham KJ. 2000. The concentration of swine production: effects on swine health, productivity, human health, and the environment. The Veterinary Clinics of North America: Food Animal Practice, Toxicology 16(3):559-97.
[119] Von Borell E, Özpinar A, Eslinger KM, Schnitz AL, Zhao Y, and Mitloehner FM. 2007. Acute and prolonged effects of ammonia on hematological variables, stress responses, performance, and behavior of nursery pigs. Journal of Swine Health and Production 15(3):137-45.
[120] PQA Plus™ producer certification handbook, p.95. www.pork.org/Producers/PQA/PQAPlusEdBook.pdf. Accessed May 5, 2010.
[121] Wathes CM, Jones JB, Kristensen HH, Jones EKM, Webster AJF. 2002. Aversion of pigs and domestic fowl to atmospheric ammonia. Transactions of the American Society of Agricultural Engineers 45(5):1605-10.
[122] Jones JB, Burgess LR, Webster AJF, and Wathes CM. 1996. Behavioural responses of pigs to atmospheric ammonia in a chronic choice test. Animal Science 63:437-45.
[123] Wathes CM, Jones JB, Kristensen HH, Jones EKM, Webster AJF. 2002. Aversion of pigs and domestic fowl to atmospheric ammonia. Transactions of the American Society of Agricultural Engineers 45(5):1605-10.
[124] Wathes CM. 2001. Aerial pollutants from weaner production. In: Varley MA and Wiseman J (eds.), The Weaner Pig: Nutrition and Management (Wallingford, U.K.: CAB International, pp. 259-71).

[125] Kim KY, Ko HJ, Kim HT, Kim CN, and Byeon SH. 2008. Association between pig activity and environmental factors in pig confinement buildings. Australian Journal of Experimental Agriculture 48:680-6.
[126] Gonyou HW, Lemay SP, and Zhang Y. 2006. Effects of the environment on productivity and disease. In: Straw BE, Zimmerman JJ, D'Allaire S, and Taylor DJ (eds.), Diseases of Swine, 9th Edition (Ames, Iowa: Blackwell Publishing, pp.1027-38).
[127] Donham KJ. 2000. The concentration of swine production: effects on swine health, productivity, human health, and the environment. The Veterinary Clinics of North America: Food Animal Practice, Toxicology 16(3):559-97.
[128] Asmar S, Pickrell JA, and Oehme FW. 2001. Pulmonary diseases caused by airborne contaminants in swine confinement buildings. Veterinary and Human Toxicology 43(1): 48-53.
[129] Rylander R, Donham KJ, Hjort C, Brouwer R, and Heederik D. 1989. Effects of exposure to dust in swine confinement buildings—a working group report. Scandinavian Journal of Work Environment & Health 15:309-12.
[130] Donham KJ. 1991. Association of environmental air contaminants with disease and productivity in swine. American Journal of Veterinary Research 52(10):1723-1730.
[131] Robertson JF, Wilson D, and Smith WJ. 1990. Atrophic rhinitis: the influence of the aerial environment. Animal Production 50:173-82.
[132] Wathes CM. 2001. Aerial pollutants from weaner production. In: Varley MA and Wiseman J (eds.), The Weaner Pig: Nutrition and Management (Wallingford, U.K.: CAB International, pp. 259-71).
[133] U.S. Department of Agriculture, Animal and Plant Health Inspection Service. 2007. Swine 2006 part I: reference of swine health and management practices in the United States. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/swine2006/Swine2006_PartI.pdf. Accessed February 21, 2010.
[134] Edwards, SA. 2004. Current developments in pig welfare. In: Thompson JE, Gill BP, and Varley MA (eds.), The Appliance of Pig Science (Nottingham, U.K., Nottingham University Press, pp. 101-15).
[135] Appleby MC. 2005. Welfare challenges in sow housing. Journal of the American Veterinary Medical Association 226(8)1334-1336.
[136] Rollin, BE. 1995. Farm Animal Welfare: Social, Bioethical, and Research Issues (Ames, IA: Iowa State University Press, p. 9).
[137] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Delmar Learning, p 291).
[138] Blackwell TE. 2004. Production practices and well-being: Swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, Iowa: Blackwell Publishing, pp. 241-69).
[139] Rydhmer L and Lundeheim N. 2008. Breeding pigs for improved welfare. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 243-70).
[140] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 388, 440).
[141] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Thompson Delmar Learning, p. 226).
[142] Grandin T (ed.). 1998. Genetics and the Behavior of Domestic Animals (San Diego, CA: Academic Publishers, pp. 122, 320.
[143] Warriss PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7:365-81.
[144] Rydhmer L and Lundeheim N. 2008. Breeding pigs for improved welfare. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 243-70.
[145] Solomon MB, van Laack, RLJM, and Eastridge JS. 1998. Biophysical basis of pale, soft, exudative (PSE) pork and poultry muscle: a review. Journal of Muscle Foods 9(1):1-11.
[146] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).
[147] Grandin T (ed.). 1998. Genetics and the Behavior of Domestic Animals (San Diego, CA: Academic Press, p. 322).

[148] Grandin T. 2007. Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, p.11).
[149] Murray AC and Johnson CP. 1998. Influence of the halothane gene on muscle quality and preslaughter death in Western Canadian pigs. Canadian Journal of Animal Science 78:543-8.
[150] Grandin T and Deesing MJ. 1998. Genetics and behavior during handling, restraint, and herding. In: Grandin T (ed.), Genetics and the Behavior of Domestic Animals (San Diego, CA: Academic Publishers, pp. 113-44).
[151] Breuer K, Sutcliffe MEM, Mercer JT, Rance KA, O'Connell NE, Sneddon IA, and Edwards SA. 2005. Heritability of clinical tail-biting and its relation to performance traits. Livestock Production Science 93:87-94.
[152] Moinard C, Mendl M, Nicol CJ, and Green LE. 2003. A case control study of on-farm risk factors for tail biting in pigs. Applied Animal Behaviour Science 81:333-55.
[153] Nielsen BL, Thodberg K, Dybkjaer L, and Vestergaard EM. 2006. Feeding behaviour in pigs. In: Bels V (ed.), Feeding in Domestic Vertebrates: from Structure to Behaviour (Wallingford, U.K.: CAB International, pp. 156-78).
[154] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 128-30).
[155] Bergeron R, Badnell-Waters AJ, Lambton S, and Mason G. 2006. Stereotypic oral behaviour in captive ungulates: foraging, diet and gastrointestinal function. In: Mason G and Rushen J (eds.), Stereotypic Animal Behaviour: Fundamentals and Applications to Welfare, 2nd Edition (Wallingford, U.K.: CABI, pp.19-57).
[156] Nielsen BL, Thodberg K, Dybkjaer L, and Vestergaard EM. 2006. Feeding behaviour in pigs. In: Bels V (ed.), Feeding in Domestic Vertebrates: from Structure to Behaviour (Wallingford, U.K.: CAB International, pp. 156-78).
[157] Eisemann JH and Argenzio RA. 1999. Effects of diet and housing density on growth and stomach morphology in pigs. Journal of Animal Science 77:2709-14.
[158] Liesner VG, Taube V, Leonhard-Marek S, Beineke A, and Kamphues J. 2009. Integrity of gastric mucosa in reared piglets – effects of physical form of diets (meal/pellets), pre-processing grinding (coarse/fine) and addition of lignocellulose (0/2.5 %). Journal of Animal Physiology and Animal Nutrition 93:373-80.
[159] Radostits OM, Gay CC, Blood DC, and Hinchcliff KW. 2000. Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, 9th Edition (New York, NY: W.B. Saunders Company Ltd., p. 1776).
[160] Kowalczyk T. 1969. Etiologic factors of gastric ulcers in swine. American Journal of Veterinary Research 30(3):393-400.
[161] Amory JR, Mackenzie AM, Pearce GP. 2006. Factors in the housing environment of finisher pigs associated with the development of gastric ulcers. Veterinary Record 158:260-4.
[162] Elbers ARW, Vos JH, and Dirkzwager A. 1995. A survey of the relationship between bile staining and oesophagogastric lesions in slaughter pigs. The Veterinary Quarterly 17(3):106-7.
[163] Guise HJ, Carlyle WWH, Penny RHC, Abbott TA, Riches HL, and Hunter EJ. 1997. Gastric ulcers in finishing pigs: their prevalence and failure to influence growth rate. The Veterinary Record 141:563-6.
[164] Robertson ID, Accioly JM, Moore KM, Driesen SJ, Pethick DW, and Hampson DJ. 2002. Risk factors for gastric ulcers in Australian pigs at slaughter. Preventive Veterinary Medicine 53:293-303.
[165] Ayles HL, Friendship RM, Bubenik GA, and Ball RO. 1999. Effect of feed particle size and dietary melatonin supplementation on gastric ulcers in swine. Canadian Journal of Animal Science 79:179-85.
[166] Radostits OM, Gay CC, Blood DC, and Hinchcliff KW. 2000. Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, 9th Edition (New York, NY: W.B. Saunders Company Ltd., p. 1776-9).
[167] Nielsen BL, Thodberg K, Dybkjaer L, and Vestergaard EM. 2006. Feeding behaviour in pigs. In: Bels V (ed.), Feeding in Domestic Vertebrates: from Structure to Behaviour (Wallingford, U.K.: CAB International, pp. 156-78).
[168] Amory JR, Mackenzie AM, Pearce GP. 2006. Factors in the housing environment of finisher pigs associated with the development of gastric ulcers. Veterinary Record 158:260-4.
[169] Guy JH, Rowlinson P, Chadwick JP, and Ellis M. 2002. Health conditions of two genotypes of growing-finishing pig in three different housing systems: implications for welfare. Livestock Production Science 75:233-43.

[170] Nielsen EK, and Ingvartsen KL. 2000. Effects of cereal disintegration method, feeding method and straw as bedding on stomach characteristics including ulcers and performance in growing pigs. Acta Agriculturae Scandinavica, Section A, Animal Science 50:30-8.
[171] Ramis G, Gómez S, Pallarés FJ, and Muñoz A. 2005. Comparison of the severity of esophagogastric, lung and limb lesions at slaughter in pigs reared under standard and enriched conditions. Animal Welfare 14:27-34.
[172] Grandin T (ed.). 1998. Genetics and the Behavior of Domestic Animals (San Diego, CA: Academic Press, p. 323).
[173] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 165,169).
[174] Wallgren P and Melin L. 2001. Weaning systems in relation to disease. In: Varley MA and Wiseman J (eds.), The Weaner Pig: Nutrition and Management (Wallingford, U.K.: CAB International, pp. 309-16).
[175] Scientific Committee on Animal Health and Animal Welfare. 1999. Report on animal welfare aspects of the use of bovine somatotrophin. http://ec.europa.eu/food/fs/sc/scah/out21_en.pdf. Accessed February 21, 2010.
[176] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Delmar Learning, p. 105).
[177] McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Delmar Learning, p. 104).
[178] Marchant-Forde JN, Lay Jr. DC, Pajor EA, Richert BT, and Schinckel AP. 2003. The effects of ractopamine on the behavior and physiology of finishing pigs. Journal of Animal Science 81:416-22.
[179] Poletto R, Richert BT, and Marchant-Forde JN. 2007. Behavioral effects of "step-up" ractopamine feeding program on finishing pigs. In: Galindo F and Alvarez L (eds.), Proceedings of the 41st International Congress of the ISAE (Merida, Mexico: International Society for Applied Ethology, p. 90).
[180] Poletto R, Cheng HW, Meisel RL, Richert BT, and Marchant-Forde JN. 2008. Effects of ractopamine feeding, gender and social rank on aggressiveness and monoamine concentrations in different brain areas of finishing pigs. In: Boyle L, O'Connell N, and Hanlon A (eds.), Proceedings of the 42nd Congress of the ISAE (Dublin, Ireland: International Society for Applied Ethology, p.83).
[181] Marchant-Forde JN, Lay Jr. DC, Pajor EA, Richert BT, and Schinckel AP. 2003. The effects of ractopamine on the behavior and physiology of finishing pigs. Journal of Animal Science 81:416-22.
[182] Poletto R, Cheng HW, Meisel RL, Richert BT, and Marchant-Forde JN. 2008. Effects of ractopamine feeding, gender and social rank on aggressiveness and monoamine concentrations in different brain areas of finishing pigs. In: Boyle L, O'Connell N, and Hanlon A (eds.), Proceedings of the 42nd Congress of the ISAE (Dublin, Ireland: International Society for Applied Ethology, p.83).
[183] Poletto R, Richert BT, and Marchant-Forde JN. 2007. Behavioral effects of "step-up" ractopamine feeding program on finishing pigs. In: Galindo F and Alvarez L (eds.), Proceedings of the 41st International Congress of the ISAE (Merida, Mexico: International Society for Applied Ethology, p. 90).
[184] Marchant-Forde JN, Lay Jr. DC, Pajor EA, Richert BT, and Schinckel AP. 2003. The effects of ractopamine on the behavior and physiology of finishing pigs. Journal of Animal Science 81:416-22.
[185] Marchant-Forde JN, Lay Jr. DC, Pajor EA, Richert BT, and Schinckel AP. 2003. The effects of ractopamine on the behavior and physiology of finishing pigs. Journal of Animal Science 81:416-22.
[186] Marchant-Forde JN, Lay Jr. DC, Pajor EA, Richert BT, and Schinckel AP. 2003. The effects of ractopamine on the behavior and physiology of finishing pigs. Journal of Animal Science 81:416-22.
[187] Grandin T. 2007. Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp.11-12).
[188] Poletto R, Rostagno MH, Richert BT, and Marchant-Forde JN. 2009. Effects of a "step-up" ractopamine feeding program, gender and social rank on growth performance, hoof lesions and Enterobacteriaceae shedding in finishing pigs. Journal of Animal Science 87:304-13.
[189] Faucitano L and Geverink NA. 2008. Effects of preslaughter handling on stress response and meat quality in pigs. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 197-224).
[190] Faucitano L. 2001. Causes of skin damage to pig carcasses. Canadian Journal of Animal Science 81:39-45.
[191] Faucitano L. 2001. Causes of skin damage to pig carcasses. Canadian Journal of Animal Science 81:39-45.

[192] Gentry JG, Johnson AK, and McGlone JJ. 2008. The welfare of growing-finishing pigs. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 133-59).
[193] Gentry JG, Johnson AK, and McGlone JJ. 2008. The welfare of growing-finishing pigs. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 133-59).
[194] Lewis C, Hulbert L, and McGlone J. 2005. Heart rate associated with routine handling in finishing pigs and Sows. Journal of Animal Science 83(supplement 1):259.
[195] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[196] Blackwell TE. 2004. Production practices and well-being: Swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, Iowa: Blackwell Publishing, p. 262).
[197] Broom DM. 2007. Quality of life means welfare: how is it related to other concepts and assessed? Animal Welfare16(Supplement):45-53.
[198] Broom DM and Fraser AF. 2007. Domestic Animal Behaviour and Welfare, 4th Edition (Wallingford, U.K.: CAB International, p.321).
[199] National Pork Board and the American Association of Swine Veterinarians Undated. On Farm Euthanasia of Swine - Options for the Producer. www.aasv.org/aasv/euthanasia.pdf. Accessed February 21, 2010.
[200] Sacks A. 2009. He hogties abuse on HBO documentary "Death on a Factory Farm". New York Daily News, March 13. www.nydailynews.com/lifestyle/2009/03/13/2009-03-13_he_hogties_abuse_on_hbo_documentary_deat.html. Accessed February 21, 2010.
[201] Miller M. 2009. Euthanasia: It's about animal care. Pork, March 1. www.porkmag.com/directories.asp?pgID=780&ed_id=7216. Accessed February 21, 2010.
[202] Shields DA and Mathews KH. 2003. Interstate livestock movements. U.S. Department of Agriculture, Electronic Outlook Report from the Economic Research Service. www.ers.usda.gov/publications/ldp/jun03/ldpm10801/ldpm10801.pdf. Accessed February 21, 2010.
[203] Bradshaw RH, Parrott RF, Forsling ML, Goode JA, Lloyd DM, Rodway RG, and Broom DM. 1996. Stress and travel sickness in pigs: effects of road transport on plasma concentrations of cortisol, beta-endorphin and lysine vasopressin. Animal Science 63:507-16.
[204] Guàrdia MD, Estany J, Balasch S, Oliver MA, Gispert M, Diestre A. 2005. Risk assessment of DFD meat due to pre-slaughter conditions in pigs. Meat Science 70(4):709-16.
[205] Bradshaw RH, Parrott RF, Goode JA, Lloyd DM, Rodway RG, and Broom DM. 1996. Behavioural and hormonal responses of pigs during transport: effect of mixing and duration of journey. Animal Science 62:547-54.
[206] Perremans S, Randall JM, Rombouts G, Decuypere E, and Geers R. 2001. Effect of whole-body vibration in the vertical axis on cortisol and adrenocroticotropic hormone levels. Journal of Animal Science 79:975-81.
[207] Warriss PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7:365-81.
[208] Schrama JW, van der Hel W, Grossen J, Henken AM, Verstegen MWA, and Noordhuizen JPTM. 1996. Required thermal thresholds during transport of animals. The Veterinary Quarterly 18(3):90-5.
[209] Ritter MJ, Ellis M, Bowman R, et al. 2008. Effects of season and distance moved during loading on transport losses of market-weight pigs in two commercially available types of trailer. Journal of Animal Science 86:317-45.
[210] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).
[211] Van Putten G and Elshof WJ. 1978. Observations on the effect of transport on the well-being and lean quality of slaughter pigs. Animal Regulation Studies 1:247-71.
[212] Warriss PD, Bevis EA, Edwards JE, Brown SN and Knowles TG. 1991. Effect of the angle of slope on the ease with which pigs negotiate loading ramps. Veterinary Record 128:419-21.
[213] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).

[214] Bradshaw RH, Parrott RF, Goode JA, Lloyd DM, Rodway RG, and Broom DM. 1996. Behavioural and hormonal responses of pigs during transport: effect of mixing and duration of journey. Animal Science 62:547-54.
[215] Averós X, Knowles T G, Brown SN, Warriss PD, and Gosálvez LF. 2008. Factors affecting the mortality of pigs being transported to slaughter. Veterinary Record 163:386-90.
[216] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).
[217] Grandin T. 2001. Livestock trucking guide: livestock management practices that reduce injuries to livestock during transport. National Institute for Animal Agriculture. www.animalagriculture.org/Education/Pamphlets/Livestock Trucking Guide.pdf. Accessed February 21, 2010.
[218] Knowles T and Warriss P. 2007. Stress physiology of animals during transport. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 312-28).
[219] Averós X, Knowles T G, Brown SN, Warriss PD, and Gosálvez LF. 2008. Factors affecting the mortality of pigs being transported to slaughter. Veterinary Record 163:386-90.
[220] Blackwell TE. 2004. Production practices and well-being: Swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, Iowa: Blackwell Publishing, p. 262).
[221] Warriss PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7:365-81.
[222] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).
[223] Bradshaw RH, Parrott RF, Forsling ML, Goode JA, Lloyd DM, Rodway RG, and Broom DM. 1996. Stress and travel sickness in pigs: effects of road transport on plasma concentrations of cortisol, beta-endorphin and lysine vasopressin. Animal Science 63:507-16.
[224] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).
[225] Bradshaw RH, Randall JM, Forsling ML, Rodway R, Goode JA, Brown SN, Broom DM. 1999. Travel sickness and meat quality in pigs. Animal Welfare 8(1):3-14.
[226] Warriss PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7:365-81.
[227] Van Putten G and Elshof WJ. 1978. Observations on the effect of transport on the well-being and lean quality of slaughter pigs. Animal Regulation Studies 1:247-71.
[228] Guárdia MD, Estany J, Balasch S, Oliver MA, Gispert M, and Diestre A. 2004. Risk assessment of PSE condition due to pre-slaughter conditions and RYR1 gene in pigs. Meat Science 67:471-8.
[229] Grandin T and Deesing MJ. 1998. Genetics and behavior during handling, restraint, and herding. In: Grandin T (ed.), Genetics and the Behavior of Domestic Animals (San Diego, CA: Academic Press, p.122).
[230] Solomon MB, van Laack, RLJM, and Eastridge JS. 1998. Biophysical basis of pale, soft, exudative (PSE) pork and poultry muscle: a review. Journal of Muscle Foods 9(1):1-11..
[231] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).
[232] Grandin T (ed.). 1998. Genetics and the Behavior of Domestic Animals (San Diego, CA: Academic Press, pp. 322-3).
[233] Barbut S, Sosnicki AA, Lonergan SM, et al. 2008. Progress in reducing the pale, soft and exudative (PSE) problem in pork and poultry meat. Meat Science 79:46-63.
[234] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[235] Schrama JW, van der Hel W, Grossen J, Henken AM, Verstegen MWA, and Noordhuizen JPTM. 1996. Required thermal thresholds during transport of animals. The Veterinary Quarterly 18(3):90-5.
[236] Schrama JW, van der Hel W, Grossen J, Henken AM, Verstegen MWA, and Noordhuizen JPTM. 1996. Required thermal thresholds during transport of animals. The Veterinary Quarterly 18(3):90-5.
[237] Ellis M, Ritter M, Anil L, et al. 2005. Welfare of finisher pigs during transportation to slaughter. Journal of Animal Science 83(Supplement 1):259.

[238] Ritter MJ, Ellis M, Brinkmann J, Keffaber KK, and Wolter BF. 2005. Relationships between transport conditions and the incidence of dead and non-ambulatory finishing pigs at the slaughter plant. Journal of Animal Science 83(Supplement 1):259.
[239] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[240] Warriss PD and SN Brown. 1994. A survey of mortality in slaughter pigs during transport and lairage. The Veterinary Record 134(20):513-5.
[241] Averós X, Knowles T G, Brown SN, Warriss PD, and Gosálvez LF. 2008. Factors affecting the mortality of pigs being transported to slaughter. Veterinary Record 163:386-90.
[242] Guàrdia MD, Estany J, Balasch S, Oliver MA, Gispert M, Diestre A. 2004. Risk assessment of PSE condition due to pre-slaughter conditions and RYR1 gene in pigs. Meat Science 67(3):471-78.
[243] Gispert M, Faucitano L Oliver MA, et al. 2000. A survey of pre-slaughter conditions, halothane gene frequency, and carcass and meat quality in five Spanish pig commercial abattoirs. Meat Science 55:97-106.
[244] Schrama JW, van der Hel W, Grossen J, Henken AM, Verstegen MWA, and Noordhuizen JPTM. 1996. Required thermal thresholds during transport of animals. The Veterinary Quarterly 18(3):90-5.
[245] Fitzgerald RF, Stalder KJ, Matthews JO, Schultz Kaster CM, Johnson AK. 2009. Factors associated with fatigued, injured, and dead pig frequency during transport and lairage at a commercial abattoir. Journal of Animal Science 87:1156-66.
[246] Gispert M, Faucitano L Oliver MA, et al. 2000. A survey of pre-slaughter conditions, halothane gene frequency, and carcass and meat quality in five Spanish pig commercial abattoirs. Meat Science 55:97-106.
[247] Ritter MJ, Ellis M, Bowman R, et al. 2008. Effects of season and distance moved during loading on transport losses of market-weight pigs in two commercially available types of trailer. Journal of Animal Science 86:317-45.
[248] Grandin T. 2001. Livestock trucking guide: livestock management practices that reduce injuries to livestock during transport. National Institute for Animal Agriculture. www.animalagriculture.org/Education/Pamphlets/Livestock Trucking Guide.pdf. Accessed February 21, 2010.
[249] U.S. Department of Agriculture National Agricultural Statistics Service. 2006. Swine 2006 part III: reference of swine health, productivity, and general management in the United States, p.42. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/swine2006/Swine2006_PartIII.pdf. Accessed February 21, 2010.
[250] Lambooij E. 2007. Transport of pigs. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, pp. 228-44).
[251] Shields DA and Mathews KH. 2003. Interstate livestock movements. U.S. Department of Agriculture, Electronic Outlook Report from the Economic Research Service. www.ers.usda.gov/publications/ldp/jun03/ldpm10801/ldpm10801.pdf. Accessed February 21, 2010.
[252] Bench C, Schaefer A, and Faucitano L. 2008. The welfare of pigs during transport. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 161-95).
[253] Wilson TM, Logan-Henfrey L, Weller R, and Kellman B. 2000. Agroterrorism, biological crimes, and biological warfare targeting animal agriculture. In: Brown C and Bolin C (eds.), Emerging Diseases of Animals (Washington, DC: ASM Press, 23-57).
[254] Wilson TM, Gregg DA, King DJ, et al. 2001. Agroterrorism, biological crimes, and biowarfare targeting animal agriculture. Laboratory Aspects of Biowarfare 21(3):549-91.
[255] Warriss PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7:365-81.
[256] Ritter MJ, Ellis M, Brinkmann J, Keffaber KK, and Wolter BF. 2005. Relationships between transport conditions and the incidence of dead and non-ambulatory finishing pigs at the slaughter plant. The fatigued pig syndrome. Journal of Animal Science 83(Supplement 1):259.
[257] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[258] Warriss PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7:365-81.

[259] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[260] Gregory NG. 2007. Animal Welfare and Meat Production, 2nd Edition (Wallingford, U.K.: CABI, p. 185).
[261] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[262] Fitzgerald RF, Stalder KJ, Matthews JO, Schultz Kaster CM, and Johnson AK. 2009. Factors associated with fatigued, injured, and dead pig frequency during transport and lairage at a commercial abattoir. Journal of Animal Science 87:1156-66.
[263] U.S. Department of Agriculture National Agricultural Statistics Service. 2010. Livestock slaughter: 2009 annual summary. http://usda.mannlib.cornell.edu/usda/current/LiveSlauSu/LiveSlauSu-04-29-2010.pdf. Accessed May 5, 2010.
[264] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[265] Warriss PD. 1994. Antemortem handling of pigs. In: Cole DJA, Wiseman J, and Varley MA (eds.), Principles of pig science (Nottingham, England: Nottingham University Press, pp. 425-32.
[266] Warriss PD. 1998. The welfare of slaughter pigs during transport. Animal Welfare 7:365-81.
[267] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[268] Ritter M, Ellis M, Benjamin M, et al. 2005. The fatigued pig syndrome. Journal of Animal Science 83(Supplement 1):258.
[269] Sutherland MA, Erlandson K, Connor JF, et al. 2008. Health of non-ambulatory, non-injured pigs at processing. Livestock Science 116:237-45.
[270] Sutherland MA, Erlandson K, Connor JF, et al. 2008. Health of non-ambulatory, non-injured pigs at processing. Livestock Science 116:237-45.
[271] Grandin T. 2007. Livestock Handling and Transport, 3rd Edition (Cambridge, MA: CABI, p.11).
[272] Blackwell TE. 2004. Production practices and well-being: Swine. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, IA: Blackwell Publishing, p. 246).
[273] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[274] Ritter MJ, Ellis M, Brinkmann J, Keffaber KK, and Wolter BF. 2005. Relationships between transport conditions and the incidence of dead and non-ambulatory finishing pigs at the slaughter plant. The fatigued pig syndrome. Journal of Animal Science 83(Supplement 1):259.
[275] Ritter MJ, Ellis M, Brinkmann J, et al. 2006. Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses. Journal of Animal Science 84:2856-64.
[276] Ritter M, Ellis M, Benjamin M, et al. 2005. The fatigued pig syndrome. Journal of Animal Science 83(Supplement 1):258.
[277] Fitzgerald RF, Stalder KJ, Matthews JO, Schultz Kaster CM, and Johnson AK. 2009. Factors associated with fatigued, injured, and dead pig frequency during transport and lairage at a commercial abattoir. Journal of Animal Science 87:1156-66.
[278] Scientific Panel for Animal Health and Welfare, European Commission. 2004. Welfare aspects of animal stunning and killing methods, p. 45-8. www.efsa.europa.eu/en/scdocs/doc/opinion_ahaw_02_ej45_stunning_report_v2_en1,0.pdf. Accessed February 21, 2010.
[279] Beaver B, Reed W, Leary S et al., 2000. Report of the AVMA panel on euthanasia. Journal of the American Veterinary Medical Association 218(5):669-96.

[280] Raj M. 2008. Welfare of pigs during stunning and slaughter. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 225-42).
[281] Scientific Panel for Animal Health and Welfare, European Commission. 2004. Welfare aspects of animal stunning and killing methods p. 45-8. www.efsa.europa.eu/en/scdocs/doc/opinion_ahaw_02_ej45_stunning_report_v2_en1,0.pdf. Accessed February 21, 2010.
[282] Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 453).
[283] Scientific Panel for Animal Health and Welfare, European Commission 2004 Welfare aspects of animal stunning and killing methods,, p. 26). www.efsa.europa.eu/en/scdocs/doc/opinion_ahaw_02_ej45_stunning_report_v2_en1,0.pdf. Accessed February 21, 2010.
[284] Gregory NG. 1998. Animal Welfare and Meat Science (Wallingford, U.K.: CABI Publishing, pp. 226, 230).
[285] Gregory NG. 1987. Determination of impaired brain function in animals in the laboratory. In: Pre-slaughter stunning of food animals (Brusels, Belgium: Economic and Social Committee of the European Communities, pp. 2-16).
[286] Daly CC, Kallweit E, and Ellendorf F. 1988. Cortical function in cattle during slaughter: conventional captive bolt stunning followed by exsanguination compared with shechita slaughter. The Veterinary Record 122:325-9.
[287] Daly CC, Gregory NG, Wotton SB, and Whittington PE. 1986. Concussive methods of pre-slaughter stunning in sheep: assessment of brain function using cortical evoked responses. Research in Veterinary Science 41:349-52.
[288] Lambooij B, Merkus GSM, Voorst NV, and Pieterse C. 1996. Effect of a low voltage with a high frequency electrical stunning on unconsciousness in slaughter pigs. Fleischwirtschaft 76(12):1327-8.
[289] Gregory NG. 1987. Determination of impaired brain function in animals in the laboratory. In: Pre-slaughter stunning of food animals (Brusels, Belgium: Economic and Social Committee of the European Communities, pp. 2-16).
[290] Raj M. 2008. Welfare of pigs during stunning and slaughter. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 225-42).
[291] Rodríguez P, Dalmau A, Ruiz-de-la-Torre JL, Manteca X, Jensen EW, Rodríguez B, Litvan H, and Velarde A. 2008. Assessment of unconsciousness during carbon dioxide stunning in pigs. Animal Welfare 17:341-9.
[292] Raj ABM. 2004. Stunning and slaughter of poultry. In: Mead GC (ed.), Poultry Meat Processing and Quality (Cambridge, U.K.: Woodhead Publishing Ltd., pp. 65-89).
[293] Raj M. 1998. Welfare during stunning and slaughter of poultry. Poultry Science 77(12):1815-9.
[294] Raj M. 2008. Welfare of pigs during stunning and slaughter. In: Faucitano L and Schaefer AL (eds.), Welfare of Pigs from Birth to Slaughter (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 225-42).
[295] Raj ABM and Gregory NG. 1996. Welfare implications of the gas stunning of pigs 2. Stress of induction of anaesthesia. Animal Welfare 5:71-8.
[296] Personal correspondence with Donald Broom, Professor of Animal Welfare, University of Cambridge, March 3, 2010.
[297] Gregory NG. 1987. Determination of impaired brain function in animals in the laboratory. In: Pre-slaughter stunning of food animals (Brusels, Belgium: Economic and Social Committee of the European Communities, pp. 2-16).
[298] Ernsting J. 1965. The effects of anoxia on the central nervous system. In: Gillies JA (ed.), A Text Book of Aviation Physiology (London, U.K.: Pergamon Press, pp. 270-89).
[299] Gregory NG. 1987. Determination of impaired brain function in animals in the laboratory. In: Pre-slaughter stunning of food animals (Brusels, Belgium: Economic and Social Committee of the European Communities, pp. 2-16).
[300] Gregory NG. 1987. Determination of impaired brain function in animals in the laboratory. In: Pre-slaughter stunning of food animals (Brusels, Belgium: Economic and Social Committee of the European Communities, pp. 2-16).
[301] Gregory NG. 1998. Animal Welfare and Meat Science (Wallingford, U.K.: CABI Publishing, pp. 227, 229).

[302] Daly CC, Kallweit E, and Ellendorf F. 1988. Cortical function in cattle during slaughter: conventional captive bolt stunning followed by exsanguination compared with shechita slaughter. The Veterinary Record 122:325-9.
[303] Forslid A. 1987. Transient neocortical, hippocampal and amygdaloid EEG silence induced by one minute inhalation of high concentration $C0_2$ in swine. Acta Physiologica Scandinavica 130:1-10.
[304] Forslid A. 1992. Muscle spasms during pre-slaughter CO2-anaesthesia in pigs. Ethical considerations. Fleischwirtschaft 72(2):167-8.
[305] Martoft L, Lomholt L, Kolthoff C, Rodriguez BE, Jensen EW, Jørgensen PF, Pedersen HD, and Forslid A. 2002. Effects of CO_2 anaesthesia on central nervous system activity in swine. Laboratory Animals 36:115-26.
[306] Hoenderken R. 1983. Electrical and carbondioxide stunning of pigs for slaughter. In: Eikelenboom G (ed.), Stunning of Animals for Slaughter (Boston, MA: Martinus Nijhoff Publishers, pp. 59–63).
[307] Rodríguez P, Dalmau A, Ruiz-de-la-Torre JL, et al. 2008. Assessment of unconsciousness during carbon dioxide stunning in pigs. Animal Welfare 17:341-9.
[308] Llonch P, Rodríguez PA, Dalmau A, Jensen EW, Manteca X, and Velarde A. 2009. Relationship between behaviour and brain activity during the inhalation of 90% CO2 in pigs. In: Proceedings of the 43rd Congress of the International Society for Applied Ethology (Carins, Australia: The Organising Committee of the 43rd ISAE Congress, p.82).
[309] Layton R. 2008. Animal needs and commercial needs. In: Dawkins MS and Bonney R (eds.), The Future of Farming: Renewing the Ancient Contract (Oxford, U.K.: Blackwell Publishing, pp.81-93).
[310] Vansickle J. 2008. 10 ways to control costs. National Hog Farmer, November 15, p. 22-3.

HSI is the international arm of the Humane Society of the United States, an animal welfare organization backed by 11 million supporters. HSI works to create a humane and sustainable world for all animals, including people, through education, support, and the promotion of respect and compassion. Celebrating animals and confronting cruelty worldwide. On the Web at www.hsi.org.