



An HSUS Report: The Welfare of Piglets in the Pig Industry

Abstract

Pig production has changed dramatically over the last several decades, and most piglets are now raised on industrialized commercial operations that confine thousands of animals on one site. In these facilities, piglets are born and reared under conditions that dramatically contrast with the natural environment they are biologically adapted to fit. In nature, a mother sow builds a nest of twigs and leaves for the birth of her litter, and, after several days, the piglets gradually begin to leave the nest, explore their environment by rooting and nibbling, and slowly integrate into a larger family group. Piglets on commercial production facilities, however, are confined to barren, metal farrowing crates. Shortly after birth, they are subjected to a number of painful mutilations, including teeth clipping, tail docking, and ear notching, and male piglets are also castrated. All of these operations are routinely performed without the benefit of any pain-relieving anesthetics or analgesics. Piglets are weaned at an unnaturally early age, at a time when they would normally nurse frequently and depend on the mother sow for protection. Lack of outlets for normal exploratory nibbling, chewing, rooting, and foraging behavior, combined with early weaning practices, may lead to the development of abnormal oral behavior, such as tail biting and belly nosing. Early mortality is commonly high. Each of these issues is a highly significant animal welfare problem in need of immediate redress.

Introduction

The raising of pigs* for meat in the United States has become increasingly concentrated into fewer, larger production facilities,¹ where the animals are confined in steel-fixtured pens² inside warehouse-like buildings with concrete floors. In just the last 15 years, the number of facilities housing thousands of pigs has increased, while the number of small farms raising fewer than 100 pigs has declined sharply.

Evolution of U.S. Pig Production Facilities from 1993 to 2008

Year	# of pigs slaughtered	# of operations by size [†]		
		1-99 pigs	2,000-4,999 pigs	5,000 pigs or more
1993	93,296,000 ³	131,160	3,390	990
1998	101,194,000 ⁴	61,730	4,805	1,915
2003	101,043,000 ⁵	44,490	4,871	2,265
2008	116,559,000 ⁶	50,680	5,370	2,920

In facilities specially designed for birthing, piglets are born to sows who are commonly confined in farrowing crates. These crates are typically 1.5 m wide by 2.1 m long (5 by 7 ft), and have slotted floors. Straw or other bedding is not usually provided, except occasionally in older buildings. These metal cages restrict the sow to a smaller portion of the crate, measuring 61 cm (24 in) wide,⁷ and prevent her from accessing the brooder area. The crates are designed so that the piglets are able to nurse from their mother between metal bars. A heat lamp

* For purposes of this report, “pig” and “pigs” refer to any porcine animal of all ages and weight classes.

[†] Figures calculated from data provided by the U.S. Department of Agriculture’s National Agriculture Statistics Service. See: www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp#top.

in the brooder area at the opposite side of the enclosure from the sow provides warmth to the piglets, and draws them away from the sow. Slotted floors are used to facilitate the collection of manure into a pit below the building.⁸

After the piglets are weaned and removed from the farrowing crate (detailed below), they are commonly confined in a “nursery unit” until they reach 18.1-27.2 kg (40-60 lb), at approximately 9 weeks old.^{9,10} Nursery facilities are highly insulated to maintain heat and are mechanically ventilated throughout the year. Pen sizes vary but might typically measure 2.4 by 3.0 m (8 by 10 ft). Composed of metal panels and plastic slatted flooring, each pen of this size holds approximately 20 pigs. “Big-pen systems,” however, each confining groups of 50-200 nursery pigs, have been developed. Feed and water are often delivered automatically. Following the nursery phase, piglets are moved to growing/finishing facilities, where they remain until they reach slaughter weight.^{11,12}

While the commercial production environment may protect piglets from temperature extremes and non-human predators, the quality of life for animals in these artificial and barren conditions is a serious welfare concern. In the confines of the industrial production facilities, pigs are denied access to pasture, unable to engage in most natural behavior, at times exposed to very poor air quality, and routinely subjected to management practices that involve painful or distressful procedures. Numerous scientific research reports confirm the common-sense notion that the welfare of young pigs is severely compromised by industrial pig production methods.

Piglet “Processing”

Shortly after birth, newborn piglets are “processed” in a series of painful mutilations. Each procedure is done by barn staff, rather than by trained veterinarians, and pain-relieving analgesia or anesthesia is rarely used.^{13,14,15} To prevent anemia and improve survival, most piglets reared indoors must also be given 1-2 iron injections during processing. In contrast, piglets raised outdoors appear to ingest enough iron from the environment so as not to require supplementation.^{16,17}

Castration

Castration is the surgical removal of the testicles, and the procedure is performed in order to prevent “boar taint,” the taste and odor characteristic of sexually intact, mature male pigs, as well as to prevent aggression and reduce handling problems.¹⁸ In the United Kingdom and Ireland, male pigs are slaughtered at a lighter weight, before they reach the age after which boar taint becomes problematic.¹⁹ However, in most countries nearly all piglets are castrated during the first days or weeks after birth. During the procedure, the piglet is restrained to minimize movement. He is held upside-down between the handler’s legs, placed into a v-trough, or put into a commercially available restraining device.²⁰ The scrotum is cut with the hooked blade of a surgical scalpel, and the exposed testicles are pushed through the incision and are cut or pulled free of connecting tissue.^{21,22}

Physiological and behavioral lines of evidence clearly demonstrate that castration is painful.^{23,24} Piglets show an acute physiological stress response to castration. The procedure induces significant increases in cortisol,^{25,26} adrenocorticotropin hormone (ACTH), and lactate compared to control animals who are handled but not castrated,²⁷ and also causes an increase in heart rate compared to piglets given an anesthetic for the surgery.²⁸ One study, however, failed to find a clear effect of castration on urinary corticosteroids and catecholamines.²⁹

Behavioral studies corroborate the physiological evidence. During the procedure, piglets show significantly more escape attempts during castration than when simply held and restrained.³⁰ Studies have identified differences in standing, sitting, walking, lying, and nursing behavior between groups of castrated and uncastrated piglets.^{31,32,33,34} Newly castrated piglets are more inactive and exhibit prostration, stiffness, and trembling. They are less social and tend to isolate themselves from group mates. Scientists have documented behavioral differences they interpreted as indicating the presence of pain (e.g., rubbing and scratching the rump and wagging the tail) for up to four days following the castration procedure.³⁵

Piglets squeal loudly when castrated, but because they also call intensely when simply restrained, scientists studying vocal evidence of pain validated the use of piglet calls in 1998 by recording and digitizing vocalizations so that they could be further analyzed for statistical differences in call rate, duration, and frequency.³⁶ Multiple studies have demonstrated that compared to sham castrated piglets (who were held and restrained, but not subjected to the actual surgical castration procedure), piglets undergoing castration display a greater vocal response, including more high frequency calls, longer call duration, and greater peak vocal frequency.^{37,38,39,40,41} A 2003 study published in the *Journal of Sound and Vibration* classified the vocalizations of piglets during restraint and castration, and reported a significant increase in the call type they termed “screams” when piglets were castrated without anaesthesia.⁴²

The fact that pain-relieving medications reduce the response to castration is unassailable evidence that the procedure hurts. The heightened vocal response to castration without anesthesia⁴³ and other behavioral changes induced by castration are diminished by providing a local anesthetic.⁴⁴ The nociceptive response—as indicated by changes in pulse rate, electroencephalogram (EEG) power, and blood pressure—is also enhanced when piglets are castrated without anesthesia.⁴⁵

It has long been assumed that young animals have reduced ability to feel pain.⁴⁶ However, the strong behavioral responses resulting from castration are not reduced by castrating animals at a younger age,^{47,48} nor is the cortisol response diminished.⁴⁹ Castration at one day of age has such a profound effect that piglets in one study had lower weights at weaning compared to those who were not castrated until they were two weeks of age.⁵⁰ Indeed, in the human literature, there is growing concern that pain experienced by infants may have long-term adverse effects.⁵¹ However, in another study, the cortisol response to the stress of handling, whether the piglets were castrated or not, was lower at 3 days of age compared to 6, 9, or 12 days of age.⁵² Thus, castration at a very young age may improve welfare (by reducing handling stress), but not because the procedure is less painful to neonatal animals.

Due in part to animal welfare concerns, many countries are shifting away from castration of unanesthetized piglets. For example, immunocastration is now approved as an alternative to surgical castration on pig production operations in Switzerland⁵³ and is being used in Australia, where a commercial vaccine (Improvac) is available. This immunization against the hormone GnRH effectively inhibits the development of the genital tract and reduces the production of reproductive hormones.⁵⁴ Additionally, Switzerland and Norway have enacted a legislative ban on the castration of pigs,^{55,56} and in the Netherlands, supermarkets and fast-food chains McDonald's and Burger King are no longer selling products from pigs castrated without anesthesia pain relief.^{57,58}

Given that the common practice of castrating unanesthetized piglets without analgesia is painful⁵⁹ the European Commission has financed a scientific and consumer investigation.⁶⁰ The PIGCAS project, a multi-year, multi-organizational effort, will review current practices and potential alternatives, among other issues, and the results will form a basis for new European Union decisions on piglet castration policy and regulation.⁶¹ Research is underway to further test and refine pain medication for piglets,⁶² in the hope of identifying protocols that are practical for use on the farm, adhere to regulatory requirements that differ between countries, and meet animal welfare expectations.

Needle Teeth Clipping

The needle teeth are eight small, tusk-shaped teeth: four on the top and four on the bottom. The rationale for clipping the needle teeth of piglets is to prevent injury to the sow's teats when her offspring nurse, as well as to prevent facial injuries to piglets as they compete for access to teats.^{63,64} In this procedure, approximately one-half of each needle tooth is cut off using wire cutters or other sharp cutting tool,^{65,66} or the teeth may be clipped to the gum line.⁶⁷

Research on this mutilation is plentiful, and evidence suggests that clipping the teeth is painful. The procedure can expose the pulp cavity to infection, clipped teeth may fracture and bleed, abscesses may form,⁶⁸ and the

gums may be damaged.⁶⁹ Clipped piglets display teeth champing following the procedure⁷⁰ and spend more time sleeping, a possible indication of sickness due to infection of mouth injuries.⁷¹ Although one study did not find physiological evidence that clipping the teeth is stressful, as measured by plasma cortisol, ACTH, glucose, and lactate,⁷² piglets have a measurably greater vocal response when they are handled and their teeth are clipped as compared to when they are handled alone without teeth clipping.⁷³ Further, significant changes in skin temperature, indicating activation of the sympathetic nervous system (another measure of stress), have also been recorded in studies of teeth clipping.⁷⁴

Based on differences in study results, scientific opinion differs on whether teeth clipping is justified. While studies have confirmed that clipping the teeth does reduce the facial lesions of piglets,^{75,76,77,78} the results of research on reductions in mammary lesions are inconsistent, with some showing fewer scratches to the teats from clipped versus intact piglets,⁷⁹ small differences depending on the number of days since birth of the litter,^{80,81} or no effect of teeth clipping on damage to the udder at all.^{82,83} At least two studies have shown that piglets with intact teeth may disturb the sow more and thus increase their risk of being laid on as she changes position,^{84,85} while another study reported greater mortality in litters of teeth-clipped piglets from young (first parity) and old (6th or greater parity) sows, and no difference in mortality for all other litters.⁸⁶ Even though clipping the teeth can reduce facial injuries, some scientists have cautioned that this benefit has to be weighed carefully against the pain and damage caused to the teeth.⁸⁷ However, other studies conclude that the possible reduction in piglet mortality, facial and udder damage, and disturbance of the sow by piglets with sharp teeth are important reasons to continue the teeth clipping practice.^{88,89}

The grinding, rather than clipping, of teeth has been considered, using an electric or battery-operated rotating grindstone. Experiments have demonstrated that grinding the teeth is an effective method for reducing the facial lesions of piglets caused by their littermates,^{90,91,92} but the results of studies that investigated damage to the teeth and gums are mixed. In a detailed histological examination of clipped, ground, and intact teeth, researchers reported that exposure of pulp cavity, pulp inflammation, and abscess formation appear sooner and are more frequent in clipped teeth compared to those shortened with a grindstone. However, the study also reported a greater percentage of ground teeth with signs of necrosis compared to clipped or unclipped teeth. The study's authors postulated that the increase in temperature caused by the motion of the grindstone on the teeth promotes cell death and tissue lysis, leading to pulp inflammation and finally to necrosis.⁹³ Grinding the teeth takes longer than clipping them,⁹⁴ exacerbating the stress of handling.⁹⁵ Further, a 2004 study found that grinding the teeth resulted in more damage to the gums than clipping them, but the researchers reported that this may have been due to the problems with the design of grinder used in the study: as the battery deteriorated, the grinding slowed, which resulted in more gum damage; the grinder was reportedly difficult to use; and the machine at times caught piglets' tongues or gums.⁹⁶

Despite shortcomings of teeth grinding, some researchers have concluded that it is a preferable method to teeth clipping,^{97,98,99} as it may be less irritating or painful,¹⁰⁰ causes fewer injuries to the mouth and teeth,^{101,102} and results in a less pronounced inflammatory response.¹⁰³ However, other scientists contend clipping is best, because it can be done more quickly,¹⁰⁴ lowers piglet mortality in some studies, and reduces facial lesions compared to grinding the teeth.¹⁰⁵ Further, it has been proposed that piglets with clipped teeth are less likely to disturb the sow compared to those with intact or ground teeth.¹⁰⁶

Other potential alternatives to fully clipping the teeth of piglets are partial tooth clipping and selective tooth clipping. It has been shown that removing one-third of the tooth, rather than fully clipping to the gum line, reduces the severity of facial lesions inflicted on other pigs, though the one published report did not measure damage to the teeth or to the sow.¹⁰⁷ With selective tooth clipping, the smallest piglets in the litter are not clipped, leaving all of their teeth intact, thereby giving them an advantage in competing for access to the mother sow's teats. One study found that the practice of selectively leaving the low-birthweight piglets' teeth intact resulted in lower mortality for these animals if they were born in large litters, yet increased mortality of higher-birthweight piglets in these same litters, resulting in no overall difference.¹⁰⁸

Given the scientific uncertainty over the welfare benefits and assaults of these varied practices, more inquiry is necessary as the sole undebatable fact is that teeth clipping is painful.

Ear Notching

Record-keeping is important to the producer, and ear notching is practiced to permanently and inexpensively identify each piglet.^{109,110} The procedure is usually done with a “V-notcher,”¹¹¹ a tool that cuts out a triangular section of flesh from the ear, measuring 4.8-6.35 mm (0.19-0.25 in).¹¹² If the procedure is delayed, a V-notcher that removes larger pieces, 12.7 mm (0.5 in) of the pig’s ear, may be used instead on older animals. The ears may bleed after they are notched and, if the size of the cut-out flesh is too large, the ear can also tear.¹¹³

There has been very little research assessing the painfulness of ear notching,¹¹⁴ but two studies report behavioral differences between piglets who were ear notched and piglets who were similarly held and restrained, but did not undergo the actual ear-notching procedure. The piglets who were ear notched displayed more grunting vocalizations, head shaking,¹¹⁵ squeals, and escape attempts.¹¹⁶

There are alternatives to ear notching, but each has associated problems: Ear tags can get torn out and lost, tattoos can be difficult to read, and transponders may migrate or be lost if not injected properly.^{117,118} While ear tagging causes a smaller wound and is faster than ear notching—and thus likely causes less handling stress—it is not pain-free.¹¹⁹ Electronic tracking systems using microchips are being tested in Europe and the United States,¹²⁰ and if the transponders can be prevented from moving, these may be a more effective method for identifying and storing information about each pig as well as a more humane alternative to ear notching in the future.

Tail Docking

The tails of young piglets are docked to prevent the development of abnormal tail-biting behavior.¹²¹ Tail biting is a serious welfare problem that may begin to occur shortly after weaning, but once established, becomes more common.¹²² Tail biting is painful for the recipient and can lead to infection and abscess formation.¹²³

To prevent tail-biting behavior, the tails of young piglets are often cut with wire cutters, an electric cauterizing blade,¹²⁴ a heated docking iron, or a sharp knife,¹²⁵ leaving a 1.9-2.54 cm (0.75-1.0 in) stub.¹²⁶ There is also a non-surgical method of tail docking in which a tight rubber ring is placed around the tail.¹²⁷

It has been demonstrated that tail docking is effective in reducing the occurrence of tail-biting behavior,^{128,129} but the procedure is acutely painful and may cause chronic pain if a neuroma forms.^{130,131} Peripheral nerves can be traced all the way to the tip of the tail, suggesting that the entire appendage is sensitive.¹³² During the procedure, the piglets reportedly scream,¹³³ squeal, grunt, attempt to escape,¹³⁴ struggle, wag their tail, or clamp it between their legs.^{135,136} Compared with sham-operated piglets who do not have their tails docked, those who are mutilated have higher peak vocal frequencies during the procedure.¹³⁷ Following tail docking, piglets may scoot on their posteriors and will spend more time sitting down compared to undocked piglets.¹³⁸

Evidence that tail docking is stressful is somewhat contradictory. Amputation with a docking iron does not produce a rise in plasma cortisol, ACTH, lactate, or β -endorphin,^{139,140,141} but conversely, at least one study found that white blood cell counts—another physiological indicator of stress—may be reduced.¹⁴² In studies measuring the effect of blunt trauma using cutting pliers, a stress response (as measured by increased blood cortisol levels and lowered white blood cell counts) was reported in one study¹⁴³ but not in another that measured cortisol and β -endorphins.¹⁴⁴

The conditions in which piglets are raised in industrial animal production facilities is one of the underlying causes of abnormal tail-biting behavior: The environment is barren and uninteresting, typically providing young pigs little or no substrate for display of biologically driven investigatory behavior, so they often begin to explore and chew pen fittings and their group mates, including their tails.^{145,146,147} Although tail biting is sporadic and

unpredictable,¹⁴⁸ and the causal basis is undoubtedly a complex interaction of multiple factors including crowding,¹⁴⁹ genetic predisposition,¹⁵⁰ management,¹⁵¹ and nutritional factors,^{152,153} environmental enrichment can help prevent the development of tail biting,¹⁵⁴ as described in the following section. Successful control of tail biting with the use of environmental enrichment is a much more humane alternative to tail docking.

Housing Conditions

Naturally curious and playful, piglets in industrial production facilities are deprived of the complex, engaging environment they would normally encounter in a more naturalistic setting, and this has a profound effect on their behavioral development. In an outdoor environment, piglets are born in a nest of twigs and grass that was carefully constructed by the mother sow.¹⁵⁵ Piglets begin rooting, chewing at objects, and sniffing the substrate within days of their birth,¹⁵⁶ and begin to follow their mother out of the nest at about ten days of age.¹⁵⁷ They are active and playful,¹⁵⁸ and grow to spend more than half of their daily time budget foraging and exploring their environment by grazing, browsing, and turning the soil using the highly sensitive disc of their snout.¹⁵⁹ It is common for piglets to root, bite, chew, and sniff at objects and the ground,¹⁶⁰ and to collect, move, and manipulate food items.¹⁶¹

Without opportunity to display normal rooting, chewing, and manipulative oral activities, piglets in industrial confinement environments often develop abnormal behavior. They may repetitively nose other pigs or parts of the pen, frequently chew the ears and tails of their companions, or simply spend more time inactive.^{162,163,164,165} Conversely, a plethora of studies have demonstrated that pigs in a more enriched environment, in which they are provided with a rooting substrate such as straw or peat show less harmful social behavior,^{166,167,168,169} including tail biting.^{170,171,172,173,174,175} Although occasional reports note tail-biting outbreaks even in straw-bedded, outdoor environments,^{176,177} it has been suggested that recurring abnormal behavior commonly seen in industrial production operations is not usually displayed by pigs who are given adequate space in more naturalistic enclosures.^{178,179}

Poor rearing environments can also lead to greater levels of aggressive behavior^{180,181} and are thought to cause chronic social stress in adult animals. A 1996 study found that the onset of puberty was delayed in subordinate females born and reared to six weeks of age in farrowing crates compared to those with access to a one-half acre outdoor enclosure. Researchers also found that subordinate pigs with access to the outdoor environment had greater daily weight gain and less stress as indicated by physiological measures of cortisol.¹⁸² A study published in 2000 also found that growth rates were improved in an environment enriched with rooting material and extra space compared to the standard, barren conditions of the industrial production setting.¹⁸³

The prevalence of play behavior can be used as an indicator of suitable environmental conditions.¹⁸⁴ Piglets show peaks in “trotting and scampering” between 2-6 weeks of age, suggesting that space for exuberant behavior is especially important during this stage of development.¹⁸⁵ Although piglets do show playful behavior even in industrial production settings,¹⁸⁶ piglets in an enriched environment play *more* than those kept in the typical, commercial conditions.^{187,188,189}

Scientists have suggested that the needs of young animals are simply not being met in the confines of the barren, commercial production facility.¹⁹⁰ A more enriched environment would greatly improve the welfare of young pigs; simply providing straw bedding would supply an outlet for natural rooting and exploratory behavior, and increase activity levels, while simultaneously decreasing the incidence of belly nosing, aggression, chewing on and licking pen mates,¹⁹¹ and often lowering the prevalence of tail-biting.¹⁹² Additionally, straw would provide thermal and physical comfort,^{193,194} and could reduce the incidence of abrasive skin lesions.¹⁹⁵ Scientists have suggested that animals may have behavioral needs,^{196,197} and that suffering may result if animals are unable to engage in certain activities.¹⁹⁸ Increased attention to these behavioral needs would greatly improve the welfare of young pigs in commercial production.

Air Quality

The air quality in industrial production facilities is often poor and is a welfare concern for young pigs. Bio-physicist Christopher Wathes of the Silsoe Research Institute has stated that the air in weaning facilities “seethes with a dense miasma of bio-aerosols and gases.” Some of the aerial pollutants to which he refers include dust, endotoxins, and ammonia.¹⁹⁹ Experiments have shown that pigs can detect and will avoid atmospheres that contain ammonia, even at concentrations as low as 10 parts per million (ppm), and that they prefer fresh air.^{200,201,202}

Poor air quality may increase the incidence and severity of certain respiratory diseases. Infectious atrophic rhinitis is a disease of pigs caused by bacterial infection of the upper respiratory tract. Initial colonization of the nasal mucosa by pathogenic bacteria is thought to occur in young pigs, and, by the time they reach slaughter weight, infected animals have inflamed nasal passages and atrophy of turbinate bone, which can lead to facial deformity in severe cases.^{203,204} Aerial concentrations of dust and ammonia in farrowing facilities are correlated with this bone atrophy and disease severity.²⁰⁵ Poor air quality may also lead to other diseases, including enzootic pneumonia, porcine reproductive and respiratory syndrome (PRRS), and swine influenza.²⁰⁶

Mortality

Piglet mortality is often high. The May 2007 issue of *National Hog Farmer* reports an average preweaning mortality rate of 13.2% with a range of 9.5-17.2% on a sampling of U.S. farms.²⁰⁷ According to a 2006 USDA survey of 92% of U.S. producers, an average of 11.5 piglets are born per litter, but only 10.5 are born alive and a further 1.1 die before weaning.²⁰⁸

Piglet mortality is often attributed to accidental crushing by the sow. Sows are normally responsive,²⁰⁹ attentive mothers who will defend their piglets when they are threatened,²¹⁰ but because they are bred for producing large litters of fast-growing piglets with high muscle (meat) mass,²¹¹ sows also grow to unprecedented size. As such, the weight discrepancy between the sow and her piglets poses a danger: a neonatal piglet may weigh only 1 kg (2.2 lb), while a breeding sow may reach about 250 kg (551 lb).²¹² A misplaced step or change in posture by the sow can easily injure or kill a newborn.

Compounding this problem is selective breeding for increased litter size. Large litters result in more undersized piglets at birth, unintentionally resulting in lower survival rates.^{213,214} Low birth-weight piglets are more likely to be crushed,²¹⁵ but in addition, piglets in large litters face increasing competition for access to the udder for nursing.²¹⁶ Another contributing factor to poor survival rates is reduced mothering ability, another unintended side-effect of genetic selection for increased litter size.²¹⁷

Piglet mortality is not only caused by accidental crushing, however, but also by a host of other interrelated problems including diarrhea (scours), deformities, respiratory afflictions, anaemia, hypothermia, small-size/non-viability, splay-legs, disease, nervous system problems, and starvation of low-birthweight piglets who do not receive adequate milk supply.^{218,219,220,221,222} Although the U.S. Department of Agriculture reports that the percentage of total mortality caused by trauma from being laid on by the sow was 45.6% in 2006,²²³ factors often interact²²⁴ and it may not always be possible to determine the cause of death for each piglet. As well, not all farms use the same criteria for classification of mortality, which makes interpretation of the data challenging. For example, in some cases, low-viability piglets may be so weak that they are unable to access a teat to nurse and would die from lack of nutrition. If, however, they do not have the strength to avoid the sow when she shifts her weight, they can be accidentally crushed, and their deaths may be categorized as a result of crushing, rather than as death caused by starvation.^{225,226} Thus, the number of deaths due to crushing by the sow may be over estimated.

Supervision of sows and piglets, especially during the birthing process, and care for low-viability piglets can substantially reduce the mortality rate including the number of stillborn piglets.^{227,228,229} An attendant can remove mucus and placental debris from the mouth and nose, dry off the piglets, and stimulate breathing. They can also prevent the newborns from becoming chilled, and can ensure that piglets receive colostrum (the first milk produced by the sow which contains antibodies important for protecting the piglet from disease).²³⁰

Facilitation of milk intake to prevent malnutrition is key for reducing mortality. According to a report for the European Commission written by the Scientific Veterinary Committee, an independent group of experts on animal behavior and welfare, “milk transfer should be considered equally as much as methods to reduce crushing.”²³¹

Another possibility for reducing piglet mortality is to selectively breed sows for desirable maternal characteristics. Some sows are more responsive than others to the distress vocalizations of their piglets,²³² and there is considerable variability in the likelihood that individual sows will crush their piglets.²³³ This suggests that there is potential to selectively breed sows for improved mothering characteristics.²³⁴ However, the use of farrowing crates may be an obstacle to selective breeding programs for improved maternal ability, because maternal behavior is so restricted that good maternal traits are less easily detected. Thus, farrowing crates are thought to have relaxed selection for good maternal behavior.²³⁵

While several studies have shown that farrowing crates can be used to reduce crushing mortality due to the fact that the sow is physically unable to access the brooder area,^{236,237,238} their use restricts the sow’s movement to such a degree that it is a considerable welfare issue.[‡] Further, a large survey in Switzerland, where restrictive farrowing crates are no longer permitted, shows that overall piglet mortality rates have not increased. In 1997, the Swiss Animal Protection Ordinance was revised, requiring that the mother sow have enough space to turn around freely. Since this law was enacted, many farms began to introduce loose farrowing systems. A survey of 482 farms using crates and 173 farms using loose housing systems found that the farrowing system had no overall effect on piglets losses. Although more piglets were crushed in loose housing systems, fewer piglets died of other causes, and the overall litter size at weaning was 9.6 piglets for both systems.²³⁹ Some alternative farrowing environments that do not severely restrict movement of the sow, but still protect piglets from being crushed include the ellipsoid farrowing crate,²⁴⁰ the sloped farrowing pen,^{241,242} and English-style, outdoor farrowing huts.^{243,244}

Early Weaning

Under commercial production conditions, the weaning process is very different than that observed in more naturalistic environments. Intake of solid feed is normally low until piglets are about five weeks of age.²⁴⁵ Naturally, the diet of piglets changes gradually,²⁴⁶ and they continue to nurse even as their reliance on milk slowly shifts to other feed types.²⁴⁷ There are reports of weaning being complete in as little as 60 days,²⁴⁸ but typically piglets are much older, up to approximately 18 weeks of age.^{249,250,251,252,253}

In contrast to the progressive change in maternal dependence during the natural weaning process, in commercial pig production operations, weaning is an abrupt, traumatic event. Young piglets are often weaned at just 2-4 weeks of age^{254,255,256} and sometimes even younger, at as little as seven days old.^{257,258,259} After they are separated from the mother, they are transferred to a nursery facility,²⁶⁰ as discussed above. Weaning imposes a number of simultaneous stressors including the sudden change in environment, diet, and social group composition, as well as maternal deprivation, leading to possible “psychological strain.”^{261,262,263} Although piglets may be given “creep feed”²⁶⁴ (access to solid feed before weaning), they consume very little,²⁶⁵ relying mostly on suckling milk from their mother for nutrition. As such, their abrupt and premature removal for artificial weaning is commonly practiced at a time when they would normally nurse frequently²⁶⁶ and maintain a strong social attachment to their mother.²⁶⁷

Piglets react strongly when they are separated from their mother.²⁶⁸ When removed from the sow and placed into a new environment at weaning, piglets often vocalize,²⁶⁹ calling in grunts and high-pitched squeals, and these vocal reactions are greater when they are hungry or underweight,²⁷⁰ or when they are weaned at three weeks of age compared with four or five weeks.²⁷¹ Sows respond to the vocalizations of their piglets by approaching and

[‡] For more information, see “An HSUS Report: The Welfare of Sows Used for Breeding in the Pig Industry” at www.humanesociety.org/assets/pdfs/farm/welfare_breeding_sows.pdf.

calling in return.^{272,273} On the first day after separation from the sow, early weaned pigs are more active and have difficulty resting.²⁷⁴ The restlessness, distress call vocalizations, and escape attempts—presumably in an effort to regain contact with their mother—are behavioral signals that scientists have attributed to emotional distress.²⁷⁵

In industrialized agriculture, the practice of prematurely weaning pigs developed largely as a means to increase productivity²⁷⁶ and efficiency²⁷⁷—i.e., the sow can be re-breed sooner, resulting in more pigs born per year. Economic pressures in commercial production require maximum “sow output,”²⁷⁸ as one pig science text book explains:

Reducing lactation length is the most effective way in which to increase sow productivity. With an adequate management program, weaning pigs at 2.5 to 4 weeks of age can be the regular practice.²⁷⁹

Piglets are also prematurely weaned in commercial production to minimize their exposure to disease.²⁸⁰ In segregated early weaning (SEW) programs, piglets weaned at 21 days or younger are subsequently housed at a different site or the sow is removed to another site, while the piglets are left in their birth place.²⁸¹ Respiratory diseases can be problematic in intensive production settings, and SEW can prevent transmission of pathogens from the sow to her piglets.²⁸² However, there is evidence that if herds are in good health, there may be little benefit to using these programs.²⁸³

Although there are disease control advantages to SEW, there are also health risks, and it has been postulated that early weaning strongly interferes with the nutritional and behavioral development of the pig.²⁸⁴ The sudden shift from mother’s milk to solid feed causes an abrupt, profound change in digestive physiology,²⁸⁵ and, in contrast to older, gradually weaned pigs,²⁸⁶ early weaned pigs often have low initial feed intake^{287,288} and underdeveloped intestinal immunity.²⁸⁹ Despite provision of highly digestible feed,²⁹⁰ these animals experience a growth setback, which is more severe when weaned at a younger age.²⁹¹ Inadequate feed intake may affect intestinal morphology and contribute to gut inflammation, compromising structure and function.²⁹² Early weaning also decreases enzyme function in the small intestine.²⁹³ Thus, early weaned piglets are predisposed to problems with dehydration, diarrhea, enteric disease (infection of the gut), and malabsorption (difficulty absorbing nutrients).²⁹⁴ Allowing piglets to suckle for a longer period would allow more time for maturation of the gut and improve gut immunity, as well as help them better digest and absorb nutrients, improving overall health.^{295,296}

Additional physiological and behavioral changes further indicate that early weaning may reduce the welfare of piglets.²⁹⁷ Immunological and hormonal investigations reveal that early weaned piglets are stressed. The ratio of neutrophils to lymphocytes, an immunological measure of stress, is higher in piglets weaned at two weeks of age compared to four weeks.²⁹⁸ Measurements of plasma and urinary concentrations of the hormone cortisol corroborate this result, also providing evidence that premature weaning is stressful.^{299,300}

Behavioral changes indicative of reduced welfare include increased aggression among early weaned piglets, intense vocalizations upon removal from the family unit, and the development of abnormal oral behavior. When different piglet litters are allowed to mix freely in a communal area prior to weaning, there is little fighting.³⁰¹ However, when piglets are introduced abruptly to unfamiliar pen mates in the manner practiced commercially, weaning aggression levels can be high.³⁰² During the first days after weaning, early weaned piglets may bite, fight, and attack their litter mates,³⁰³ and aggression levels are higher when piglets are weaned at 12 or 21 days compared to 42 days of age.³⁰⁴

It is well-established that early weaning contributes to the development of abnormal oral behavior. Early weaned piglets may engage in flank sucking³⁰⁵ nosing, biting, and chewing on other pigs or objects.^{306,307} Belly-nosing, a stereotypy—an abnormal, repetitive behavioral pattern that stems from an “environmental deficit causing frustration or [Central Nervous System] CNS dysfunction”³⁰⁸—has also been documented in early-weaned piglets. Nursing piglets perform massaging and nosing movements on the sow’s udder to encourage milk secretion, sometimes falling asleep next to her after feeding. However, when piglets are weaned early, they often redirect this massaging and nosing behavior to the belly of a pen-mate instead.^{309,310,311} Many studies show that

the earlier piglets are weaned, the more likely they are to develop stereotypic belly-nosing,^{312,313,314,315} and the more likely it is to persist.³¹⁶

While there has been little research on the nature of the bond between mother pigs and their offspring, studies of other mammalian species suggest that the mother is more than just a source of warmth and milk to the young, which may be part of the reason premature separation can have long-term effects on behavioral development.³¹⁷ Studies have further demonstrated that early maternal deprivation may interfere with the psychobiological and neuroendocrine systems of the maturing brain.³¹⁸ For primates and rodents, there is accumulating evidence that early traumatic experiences can alter brain function in a way that causes maladaptive changes in the animal's ability to respond to stress.^{319,320} For piglets, it is known that abnormal, repetitive oral behavior is associated with altered neurotransmitter activity in the basal ganglia of the brain.³²¹ Early weaning of piglets also affects the expression of certain enzymes, hormones, and hormone receptors that regulate the stress response in the hippocampal region of the brain. These changes may underlie cognitive and behavioral defects of adult animals.³²²

Conclusion

The monumental changes in the size and intensity of animal production systems from small, diversified farming enterprises to massive confinement operations have had an immense impact on the welfare of pigs in agriculture. Traditional husbandry practices have given way to the industrial model of production, and the sentient nature of the animals used has gone unrecognized. Managed simply as production units, profitability has taken precedence over animal welfare.

Farmed animal production industries often claim that their practices should be based on science³²³ and that animals in industrial operations have good welfare. However, science has clearly demonstrated that: 1) castration, amputation of the tail, and clipping the teeth are painful mutilations; 2) rearing young pigs in an impoverished, barren environment often leads to the development of abnormal behavior; 3) the air quality in industrial production environments is poor; and 4) early weaning is stressful and results in digestive, behavioral, and neurological maladies. All of these practices clearly result in poor welfare of the animals, yet they persist, demonstrating that science is not what shapes conventional production practices.

While science is important for establishing factual information about animal welfare, such as the suitability of one environment over another, for example, the ultimate decision to reject or accept such a production practice, is an ethical one.³²⁴ Baby pigs have behavioral and social needs that are not met in the restrictive, barren environments provided by industrial agriculture. At the least, basic, minimal standards for their care and treatment are in order, and more thorough consideration of the ethical implications of current practices is needed in the pig production industry, with greater emphasis on the well-being of the animals.

¹ U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services, National Animal Health Monitoring System. 2008. Swine 2006 Part IV: Changes in the U.S. Pork Industry, 1990-2006, pp. 8-11. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/swine2006/Swine2006_PartIV.pdf. Accessed June 10, 2010.

² Funk T, Harmon J, Schnitlay G. 1999. Agricultural Engineers Digest 46: Swine Wean-to-Finish Buildings (Ames, IA: MidWest Plan Service, p. 12).

³ U.S. Department of Agriculture National Agriculture Statistics Service. 1994. Livestock slaughter: 1993 summary, p. 3. <http://usda.mannlib.cornell.edu/usda/nass/LiveSlauSu//1990s/1994/LiveSlauSu-03-00-1994.pdf>. Accessed June 10, 2010.

⁴ U.S. Department of Agriculture National Agriculture Statistics Service. 1999. Livestock slaughter: 1998 summary, p. 3. <http://usda.mannlib.cornell.edu/usda/nass/LiveSlauSu//1990s/1999/LiveSlauSu-03-05-1999.pdf>. Accessed June 10, 2010.

⁵ U.S. Department of Agriculture National Agriculture Statistics Service. 2004. Livestock slaughter: 2003 summary, p. 3. <http://usda.mannlib.cornell.edu/usda/nass/LiveSlauSu//2000s/2004/LiveSlauSu-05-04-2004.pdf>. Accessed June 10, 2010.

-
- ⁶ U.S. Department of Agriculture National Agriculture Statistics Service. 2009. Livestock slaughter: 2008 summary, p. 3. <http://usda.mannlib.cornell.edu/usda/nass/LiveSlauSu/2000s/2009/LiveSlauSu-03-06-2009.pdf>. Accessed June 10, 2010.
- ⁷ Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 396).
- ⁸ Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 377, 396).
- ⁹ Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 396).
- ¹⁰ McGlone J and Pond W. 2003. Pig Production: Biological Principles and Applications (Clifton Park, NY: Thomson Delmar Learning, p. 20).
- ¹¹ Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 396-7).
- ¹² Evans M. 2001. Practical management and housing of the young weaned piglet. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K: CABI Publishing, pp. 299-307).
- ¹³ 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. 251).
- ¹⁴ Prunier A, Bonneau M, von Borell EH, et al. 2006. A review of the welfare consequences of surgical castration in piglets and the evaluation of non-surgical methods. *Animal Welfare* 15:277-89.
- ¹⁵ Noonan GJ, Rand JS, Priest J, Ainscow J, and Blackshaw JK. 1994. Behavioural observations of piglets undergoing tail docking, teeth clipping and ear notching. *Applied Animal Behaviour Science* 39:203-13.
- ¹⁶ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹⁷ Puppe B, Meunier-Salaun MC, Otten W, and Orgeur P. 2008. The welfare of piglets. In: Faucitano L and Schaefer AL (eds.), *Welfare of Pigs from Birth to Slaughter* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 97-131).
- ¹⁸ Carroll JA, Berg EL, Strauch TA, Roberts MP, and Kattesh HG. 2006. Hormonal profiles, behavioral responses, and short-term growth performance after castration of pigs at three, six, nine, or twelve days of age. *Journal of Animal Science* 84:1271-8.
- ¹⁹ Beek ter V. 2008. Europe moves away from conventional castration. *Pig Progress* 24(8):12-3.
- ²⁰ Prunier A, Bonneau M, von Borell EH, et al. 2006. A review of the welfare consequences of surgical castration in piglets and the evaluation of non-surgical methods. *Animal Welfare* 15:277-89.
- ²¹ Prunier A, Bonneau M, von Borell EH, et al. 2006. A review of the welfare consequences of surgical castration in piglets and the evaluation of non-surgical methods. *Animal Welfare* 15:277-89.
- ²² Holden PJ and Ensminger ME. 2006. Swine Science, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 365-6).
- ²³ EFSA Scientific Panel on Animal Health and Welfare. 2004. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare aspects of the castration of piglets. *The EFSA Journal* 91:1-18. www.efsa.europa.eu/cs/BlobServer/Scientific_Opinion/opinion_ahaw03_ej91_pigcast_v2_en1.0.pdf?ssbinary=true. Accessed June 2, 2010.
- ²⁴ von Borell E, Baumgartner J, Giersing M, et al. 2009. Animal welfare implications of surgical castration and its alternatives in pigs. *Animal* 3(11):1488-96.
- ²⁵ Prunier A, Mounier AM, and Hay M. 2005. Effects of castration, tooth resection, or tail docking on plasma metabolites and stress hormones in young pigs. *Journal of Animal Science* 83:216-22.
- ²⁶ Carroll JA, Berg EL, Strauch TA, Roberts MP, and Kattesh HG. 2006. Hormonal profiles, behavioral responses, and short-term growth performance after castration of pigs at three, six, nine, or twelve days of age. *Journal of Animal Science* 84:1271-8.
- ²⁷ Prunier A, Mounier AM, and Hay M. 2005. Effects of castration, tooth resection, or tail docking on plasma metabolites and stress hormones in young pigs. *Journal of Animal Science* 83:216-22.

-
- ²⁸ White RG, DeShazer JA, Tressler CJ, et al. 1995. Vocalization and physiological response of pigs during castration with or without a local anesthetic. *Journal of Animal Science* 73:381-6.
- ²⁹ Hay M, Vulin A, Génin S, Sales P, Prunier A. 2003. Assessment of pain induced by castration in piglets: behavioral and physiological responses over the subsequent 5 days. *Applied Animal Behaviour Science* 82:201-18.
- ³⁰ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ³¹ McGlone JJ, Nicholson RI, Hellman JM, and Herzog DN. 1993. The development of pain in young pigs associated with castration and attempts to prevent castration-induced behavioral changes. *Journal of Animal Science* 71:1441-6.
- ³² McGlone JJ and Hellman JM. 1988. Local and general anesthetic effects on behavior and performance of two- and seven-week-old castrated and uncastrated piglets. *Journal of Animal Science* 66:3049-58.
- ³³ Taylor AA, Weary DM, Lessard M, and Braithwaite L. 2001. Behavioural responses of piglets to castration: the effect of piglet age. *Applied Animal Behaviour Science* 73:35-43.
- ³⁴ Hay M, Vulin A, Génin S, Sales P, Prunier A. 2003. Assessment of pain induced by castration in piglets: behavioral and physiological responses over the subsequent 5 days. *Applied Animal Behaviour Science* 82:201-18.
- ³⁵ Hay M, Vulin A, Génin S, Sales P, Prunier A. 2003. Assessment of pain induced by castration in piglets: behavioral and physiological responses over the subsequent 5 days. *Applied Animal Behaviour Science* 82:201-18.
- ³⁶ Weary DM, Braithwaite LA, and Fraser D. 1998. Vocal response to pain in piglets. *Applied Animal Behaviour Science* 56:161-72.
- ³⁷ Weary DM, Braithwaite LA, and Fraser D. 1998. Vocal response to pain in piglets. *Applied Animal Behaviour Science* 56:161-72.
- ³⁸ Taylor AA and Weary DM. 2000. Vocal responses of piglets to castration: identifying procedural sources of pain. *Applied Animal Behaviour Science* 70:17-26.
- ³⁹ Taylor AA, Weary DM, Lessard M, and Braithwaite L. 2001. Behavioural responses of piglets to castration: the effect of piglet age. *Applied Animal Behaviour Science* 73:35-43.
- ⁴⁰ Puppe B, Schön PC, Tuchscherer A, Manteuffel G. 2005. Castration-induced vocalization in domestic piglets, *Sus scrofa*: Complex and specific alterations of the vocal quality. *Applied Animal Behaviour Science* 95:67-78.
- ⁴¹ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ⁴² Marx G, Horn T, Thielebein J, Knubel B, and von Borell E. 2003. Analysis of pain-related vocalization in young pigs. *Journal of Sound and Vibration* 266:687-98.
- ⁴³ White RG, DeShazer JA, Tressler CJ, et al. 1995. Vocalization and physiological response of pigs during castration with or without a local anesthetic. *Journal of Animal Science* 73:381-6.
- ⁴⁴ McGlone JJ and Hellman JM. 1988. Local and general anesthetic effects on behavior and performance of two- and seven-week-old castrated and uncastrated piglets. *Journal of Animal Science* 66:3049-58.
- ⁴⁵ Haga HA and Ranheim B. 2005. Castration of piglets: the analgesic effects of intratesticular and intrafunicular lidocaine injection. *Veterinary Anaesthesia and Analgesia* 32:1-9.
- ⁴⁶ Puppe B, Meunier-Salaun MC, Otten W, and Orgeur P. 2008. The welfare of piglets. In: Faucitano L and Schaefer AL (eds.), *Welfare of Pigs from Birth to Slaughter* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 97-131).
- ⁴⁷ Taylor AA, Weary DM, Lessard M, and Braithwaite L. 2001. Behavioural responses of piglets to castration: the effect of piglet age. *Applied Animal Behaviour Science* 73:35-43.
- ⁴⁸ McGlone JJ, Nicholson RI, Hellman JM, and Herzog DN. 1993. The development of pain in young pigs associated with castration and attempts to prevent castration-induced behavioral changes. *Journal of Animal Science* 71:1441-6.

-
- ⁴⁹ Carroll JA, Berg EL, Strauch TA, Roberts MP, and Kattesh HG. 2006. Hormonal profiles, behavioral responses, and short-term growth performance after castration of pigs at three, six, nine, or twelve days of age. *Journal of Animal Science* 84:1271-8.
- ⁵⁰ McGlone JJ, Nicholson RI, Hellman JM, and Herzog DN. 1993. The development of pain in young pigs associated with castration and attempts to prevent castration-induced behavioral changes. *Journal of Animal Science* 71:1441-6.
- ⁵¹ Puchalski M and Hummel P. 2002. The reality of neonatal pain. *Advances in Neonatal Care* 2(5):233-47.
- ⁵² Carroll JA, Berg EL, Strauch TA, Roberts MP, and Kattesh HG. 2006. Hormonal profiles, behavioral responses, and short-term growth performance after castration of pigs at three, six, nine, or twelve days of age. *Journal of Animal Science* 84:1271-8.
- ⁵³ Beek ter V. 2008. Europe moves away from conventional castration. *Pig Progress* 24(8):12-3.
- ⁵⁴ Prunier A, Bonneau M, von Borell EH, et al. 2006. A review of the welfare consequences of surgical castration in piglets and the evaluation of non-surgical methods. *Animal Welfare* 15:277-89.
- ⁵⁵ PigProgress.Net. 2009. Updated: Swiss castration opponents team up. March 13. www.pigprogress.net/news/swiss-group-against-the-compulsory-castration-of-piglets-2701.html. Accessed May 17, 2010.
- ⁵⁶ Harper A. 2008. Castration of pigs. The Pig Site. www.thepigsite.com/articles/1/health-and-welfare/2137/castration-of-pigs. Accessed May 17, 2010.
- ⁵⁷ Harper A. 2008. Castration of pigs. The Pig Site. www.thepigsite.com/articles/1/health-and-welfare/2137/castration-of-pigs. Accessed May 17, 2010.
- ⁵⁸ Beek ter V. 2008. Europe moves away from conventional castration. *Pig Progress* 24:12-3.
- ⁵⁹ Institute for Agricultural and Fisheries Research (Instituut voor Landbouw en Visserijonderzoek, ILVO). Castration of piglets in Flanders and Europe: attitudes, practice and state of the art. www.ilvo.vlaanderen.be/EN/Research/Animalhusbandryandwelfare/Pighusbandry/PIGCAS/tabid/550/Default.aspx. Accessed June 2, 2010.
- ⁶⁰ Harris C. 2008. Balancing pig welfare, castration and boar taint. *Research Watch*, April 2009, pp. 66-8. www.livestockwelfare.com/research/09aprwatch.pdf. Accessed June 2, 2010.
- ⁶¹ Institute for Agricultural and Fisheries Research (Instituut voor Landbouw en Visserijonderzoek, ILVO). Castration of piglets in Flanders and Europe: attitudes, practice and state of the art. www.ilvo.vlaanderen.be/EN/Research/Animalhusbandryandwelfare/Pighusbandry/PIGCAS/tabid/550/Default.aspx. Accessed June 2, 2010.
- ⁶² von Borell E, Baumgartner J, Giersing M, et al. 2009. Animal welfare implications of surgical castration and its alternatives in pigs. *Animal* 3(11):1488-96.
- ⁶³ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 363).
- ⁶⁴ Liptrap DO, Bailey JH, and O'Neal J. 1976. Baby pig management – birth to weaning. *Pork Industry Handbook leaflet*, Purdue University Cooperative Extension, West Lafayette, Indiana, p. 2.
- ⁶⁵ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 363).
- ⁶⁶ Liptrap DO, Bailey JH, and O'Neal J. 1976. Baby pig management – birth to weaning. *Pork Industry Handbook leaflet*, Purdue University Cooperative Extension, West Lafayette, Indiana, p. 2.
- ⁶⁷ Weary DM and Fraser D. 1999. Partial tooth-clipping of suckling pigs: effects on neonatal competition and facial injuries. *Applied Animal Behaviour Science* 65:21-7.
- ⁶⁸ Hay M, Rue J, Sansac C, Brunel G, and Prunier A. 2004. Long-term detrimental effects of tooth clipping or grinding in piglets: a histological approach. *Animal Welfare* 13:27-32.
- ⁶⁹ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ⁷⁰ Noonan GJ, Rand JS, Priest J, Ainscow J, and Blackshaw JK. 1994. Behavioural observations of piglets undergoing tail docking, teeth clipping and ear notching. *Applied Animal Behaviour Science* 39:203-13.
- ⁷¹ Lewis E, Boyle LA, Lynch PB, Brophy P, and O'Doherty JV. 2005. The effect of two teeth resection procedures on the welfare of piglets in farrowing crates. Part 1. *Applied Animal Behaviour Science* 90:233-49.

-
- ⁷² Prunier A, Mounier AM, and Hay M. 2005. Effects of castration, tooth resection, or tail docking on plasma metabolites and stress hormones in young pigs. *Journal of Animal Science* 83:216-22.
- ⁷³ Noonan GJ, Rand JS, Priest J, Ainscow J, and Blackshaw JK. 1994. Behavioural observations of piglets undergoing tail docking, teeth clipping and ear notching. *Applied Animal Behaviour Science* 39:203-13.
- ⁷⁴ Moya SL, Boyle LA, Lynch PB, and Arkins S. 2006. Influence of teeth resection on the skin temperature and acute phase response in newborn piglets. *Animal Welfare* 15:291-7.
- ⁷⁵ Brown JME, Edwards SA, Smith WJ, Thompson E, and Duncan J. 1996. Welfare and production implications of teeth clipping and iron injection of piglets in outdoor systems in Scotland. *Preventive Veterinary Medicine* 27:95-105.
- ⁷⁶ Gallois M, Le Cozler Y, Prunier A. 2005. Influence of tooth resection in piglets on welfare and performance. *Preventive Veterinary Medicine* 69:13-23.
- ⁷⁷ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ⁷⁸ Weary DM and Fraser D. 1999. Partial tooth-clipping of suckling pigs: effects on neonatal competition and facial injuries. *Applied Animal Behaviour Science* 65:21-7.
- ⁷⁹ Boyle L and Boyle RB. 2002. Effect of leaving piglets' teeth intact on sow behaviour and welfare in farrowing crates. In: Koene P, Spruijt B, Blokhuis H, et al. (eds.), *Proceedings of the 36th International Congress of the ISAE (Wageningen, The Netherlands: International Society for Applied Ethology, p. 60)*. www.applied-ethology.org/isaameetings_files/2002%20ISAE%20in%20Egmond%20aan%20Zee,%20Netherlands.pdf. Accessed June 2, 2010.
- ⁸⁰ Gallois M, Le Cozler Y, Prunier A. 2005. Influence of tooth resection in piglets on welfare and performance. *Preventive Veterinary Medicine* 69:13-23.
- ⁸¹ Lewis E, Boyle LA, Brophy P, O'Doherty JV, and Lynch PB. 2005. The effect of two piglet teeth resection procedures on the welfare of sows in farrowing crates. Part 2. *Applied Animal Behaviour Science* 90:251-64.
- ⁸² Brown JME, Edwards SA, Smith WJ, Thompson E, and Duncan J. 1996. Welfare and production implications of teeth clipping and iron injection of piglets in outdoor systems in Scotland. *Preventive Veterinary Medicine* 27:95-105.
- ⁸³ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ⁸⁴ Lewis E, Boyle LA, Lynch PB, Brophy P, and O'Doherty JV. 2005. The effect of two teeth resection procedures on the welfare of piglets in farrowing crates. Part 1. *Applied Animal Behaviour Science* 90:233-49.
- ⁸⁵ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ⁸⁶ Bates RO, Hoge MD, Edwards DB, and Straw BE. 2003. The influence of canine teeth clipping on nursing and nursery pig performance. *Journal of Swine Health and Production* 11(2):75-9.
- ⁸⁷ Gallois M, Le Cozler Y, Prunier A. 2005. Influence of tooth resection in piglets on welfare and performance. *Preventive Veterinary Medicine* 69:13-23.
- ⁸⁸ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ⁸⁹ Lewis E, Boyle LA, Brophy P, O'Doherty JV, and Lynch PB. 2005. The effect of two piglet teeth resection procedures on the welfare of sows in farrowing crates. Part 2. *Applied Animal Behaviour Science* 90:251-64.
- ⁹⁰ Gallois M, Le Cozler Y, Prunier A. 2005. Influence of tooth resection in piglets on welfare and performance. *Preventive Veterinary Medicine* 69:13-23.
- ⁹¹ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ⁹² Lewis E, Boyle LA, Lynch PB, Brophy P, and O'Doherty JV. 2005. The effect of two teeth resection procedures on the welfare of piglets in farrowing crates. Part 1. *Applied Animal Behaviour Science* 90:233-49.
- ⁹³ Hay M, Rue J, Sansac C, Brunel G, and Prunier A. 2004. Long-term detrimental effects of tooth clipping or grinding in piglets: a histological approach. *Animal Welfare* 13:27-32.
- ⁹⁴ Lewis E, Boyle LA, Lynch PB, Brophy P, and O'Doherty JV. 2005. The effect of two teeth resection procedures on the welfare of piglets in farrowing crates. Part 1. *Applied Animal Behaviour Science* 90:233-49.

-
- ⁹⁵ Moya SL, Boyle LA, Lynch PB, and Arkins S. 2006. Influence of teeth resection on the skin temperature and acute phase response in newborn piglets. *Animal Welfare* 15:291-7.
- ⁹⁶ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ⁹⁷ Lewis E, Boyle LA, Lynch PB, Brophy P, and O'Doherty JV. 2005. The effect of two teeth resection procedures on the welfare of piglets in farrowing crates. Part 1. *Applied Animal Behaviour Science* 90:233-49.
- ⁹⁸ Moya SL, Boyle LA, Lynch PB, and Arkins S. 2006. Influence of teeth resection on the skin temperature and acute phase response in newborn piglets. *Animal Welfare* 15:291-7.
- ⁹⁹ Hay M, Rue J, Sansac C, Brunel G, and Prunier A. 2004. Long-term detrimental effects of tooth clipping or grinding in piglets: a histological approach. *Animal Welfare* 13:27-32.
- ¹⁰⁰ Lewis E, Boyle LA, Lynch PB, Brophy P, and O'Doherty JV. 2005. The effect of two teeth resection procedures on the welfare of piglets in farrowing crates. Part 1. *Applied Animal Behaviour Science* 90:233-49.
- ¹⁰¹ Lewis E, Boyle LA, Lynch PB, Brophy P, and O'Doherty JV. 2005. The effect of two teeth resection procedures on the welfare of piglets in farrowing crates. Part 1. *Applied Animal Behaviour Science* 90:233-49.
- ¹⁰² Hay M, Rue J, Sansac C, Brunel G, and Prunier A. 2004. Long-term detrimental effects of tooth clipping or grinding in piglets: a histological approach. *Animal Welfare* 13:27-32.
- ¹⁰³ Moya SL, Boyle LA, Lynch PB, and Arkins S. 2006. Influence of teeth resection on the skin temperature and acute phase response in newborn piglets. *Animal Welfare* 15:291-7.
- ¹⁰⁴ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹⁰⁵ Holyoake PK, Broek DJ, and Callinan APL. 2004. The effects of reducing the length of canine teeth in sucking pigs by clipping or grinding. *Australian Veterinary Journal* 82(9):574-6.
- ¹⁰⁶ Lewis E, Boyle LA, Brophy P, O'Doherty JV, and Lynch PB. 2005. The effect of two piglet teeth resection procedures on the welfare of sows in farrowing crates. Part 2. *Applied Animal Behaviour Science* 90:251-64.
- ¹⁰⁷ Weary DM and Fraser D. 1999. Partial tooth-clipping of suckling pigs: effects on neonatal competition and facial injuries. *Applied Animal Behaviour Science* 65:21-7.
- ¹⁰⁸ Robert S, Thompson BK, and Fraser D. 1995. Selective tooth clipping in management of low-birth-weight piglets. *Canadian Journal of Animal Science* 75:285-9.
- ¹⁰⁹ Liptrap DO, Bailey JH, and O'Neal J. 1976. Baby pig management – birth to weaning. *Pork Industry Handbook leaflet*, Purdue University Cooperative Extension, West Lafayette, Indiana, p. 2.
- ¹¹⁰ Widowski T and Torrey S. 2002. Neonatal management practices. National Pork Board, Swine Welfare Factsheet 1(6).
- ¹¹¹ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 364).
- ¹¹² Brady SE and Reese DE. 2008. Proper way to ear notch pigs. NebGuide. www.ianrpubs.unl.edu/epublic/live/g1880/build/g1880.pdf. Accessed June 2, 2010.
- ¹¹³ Brady SE and Reese DE. 2008. Proper way to ear notch pigs. NebGuide. www.ianrpubs.unl.edu/epublic/live/g1880/build/g1880.pdf. Accessed June 2, 2010.
- ¹¹⁴ Widowski T and Torrey S. 2002. Neonatal management practices. National Pork Board, Swine Welfare Factsheet 1(6).
- ¹¹⁵ Noonan GJ, Rand JS, Priest J, Ainscow J, and Blackshaw JK. 1994. Behavioural observations of piglets undergoing tail docking, teeth clipping and ear notching. *Applied Animal Behaviour Science* 39:203-13.
- ¹¹⁶ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹¹⁷ Widowski T and Torrey S. 2002. Neonatal management practices. National Pork Board, Swine Welfare Factsheet 1(6).
- ¹¹⁸ Madec F, Geers R, Vesseur P, Kjeldsen N, and Blaha T. 2001. Traceability in the pig production chain. *Revue Scientifique et Technique de l'Office International des Epizooties* 20(2):523-37.

-
- ¹¹⁹ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹²⁰ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 364-5).
- ¹²¹ McGlone JJ, Sells J, Harris S, and Hurst RJ. 1990. Cannibalism in growing pigs: effects of tail docking and housing system on behavior, performance and immune function. Texas Tech Univ. Agric. Sci. Tech. Rep. No. T-5-283, pp. 69-71. www.depts.ttu.edu/liru_afs/PDF/CANNIBALISMGROWINGPIGS.pdf. Accessed June 2, 2010.
- ¹²² Held S and Mendl M. 2001. Behaviour of the young weaner pig. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 273-97).
- ¹²³ Schröder-Petersen DL and Simonsen HB. 2001. Tail biting in pigs. *The Veterinary Journal* 162:196-210.
- ¹²⁴ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 363-4).
- ¹²⁵ Sutherland MA, Bryer PJ, Krebs N, and McGlone JJ. 2008. Tail docking in pigs: acute physiological and behavioural responses. *Animal* 2(2):292-7.
- ¹²⁶ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 363-4).
- ¹²⁷ Sutherland MA, Bryer PJ, Krebs N, and McGlone JJ. 2008. Tail docking in pigs: acute physiological and behavioural responses. *Animal* 2(2):292-7.
- ¹²⁸ Hunter EJ, Jones TA, Guise HJ, Penny RHC, and Hoste S. 2001. The relationship between tail biting in pigs, docking procedure and other management practices. *The Veterinary Journal* 161:72-9.
- ¹²⁹ Sutherland MA, Bryer PJ, Krebs N and McGlone JJ. 2009. The effect of method of tail docking on tail-biting behaviour and welfare of pigs. *Animal Welfare* 18:561-70.
- ¹³⁰ European Food Safety Authority. 2007. The risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems, Scientific Opinion of the Panel on Animal Health and Welfare. *The EFSA Journal* 611:1-13. www.efsa.europa.eu/en/scdocs/doc/611.pdf. Accessed June 2, 2010.
- ¹³¹ Simonsen HB, Klinken L, and Bendseil E. 1991. Histopathology of intact and docked pigtails. *British Veterinary Journal* 147:407-12.
- ¹³² Simonsen HB, Klinken L, and Bendseil E. 1991. Histopathology of intact and docked pigtails. *British Veterinary Journal* 147:407-12.
- ¹³³ European Food Safety Authority. 2007. Scientific Report on the risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. Annex to the EFSA Journal 611:1-13. www.efsa.europa.eu/cs/BlobServer/Scientific_Opinion/ahaw_report_pigwelfare_tailbiting_en.pdf?ssbinary=true Accessed June 2, 2010.
- ¹³⁴ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹³⁵ Noonan GJ, Rand JS, Priest J, Ainscow J, and Blackshaw JK. 1994. Behavioural observations of piglets undergoing tail docking, teeth clipping and ear notching. *Applied Animal Behaviour Science* 39:203-13.
- ¹³⁶ Torrey S, Devillers N, Lessard M, Farmer C, and Widowski T. 2009. Effect of age on the behavioral and physiological responses of piglets to tail docking and ear notching. *Journal of Animal Science* 87:1778-86.
- ¹³⁷ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹³⁸ Sutherland MA, Bryer PJ, Krebs N, and McGlone JJ. 2008. Tail docking in pigs: acute physiological and behavioural responses. *Animal* 2(2):292-7.
- ¹³⁹ Prunier A, Mounier AM, and Hay M. 2005. Effects of castration, tooth resection, or tail docking on plasma metabolites and stress hormones in young pigs. *Journal of Animal Science* 83:216-22.

-
- ¹⁴⁰ Sutherland MA, Bryer PJ, Krebs N, and McGlone JJ. 2008. Tail docking in pigs: acute physiological and behavioural responses. *Animal* 2(2):292-7.
- ¹⁴¹ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹⁴² Sutherland MA, Bryer PJ, Krebs N, and McGlone JJ. 2008. Tail docking in pigs: acute physiological and behavioural responses. *Animal* 2(2):292-7.
- ¹⁴³ Sutherland MA, Bryer PJ, Krebs N, and McGlone JJ. 2008. Tail docking in pigs: acute physiological and behavioural responses. *Animal* 2(2):292-7.
- ¹⁴⁴ Marchant-Forde JN, Lay DC, McMunn KA, Cheng HW, Pajor EA, and Marchant-Forde RM. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. *Journal of Animal Science* 87:1479-92.
- ¹⁴⁵ Van de Weerd HA, 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* 80:289-98.
- ¹⁴⁶ Van Putten G and Dammers J. 1976. A comparative study of the well-being of piglets reared conventionally and in cages. *Applied Animal Ethology* 2:339-56.
- ¹⁴⁷ Day JEL, Van de Weerd HA, 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.
- ¹⁴⁸ Edwards SA. 2006. Tail biting in pigs: understanding the intractable problem. *The Veterinary Journal* 171:198-9.
- ¹⁴⁹ Scientific Veterinary Committee. 1997. *The Welfare of Intensively Kept Pigs*, section 4.4.2. http://ec.europa.eu/food/animal/welfare/farm/out17_en.pdf. Accessed June 2, 2010, citing: Madsen A, Nielsen EK, and Hansen LL. 1976. Some Danish experiments on the influence of housing systems on the performance of growing pigs. US Feed Grains Council, Hamburg.
- ¹⁵⁰ 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.
- ¹⁵¹ 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.
- ¹⁵² Fraser D. 1987. Mineral-deficient diets and the pig's attraction to blood: implications for tail-biting. *Canadian Journal of Animal Science* 67:909-18.
- ¹⁵³ Fraser D, Bernon DE, and Ball RO. 1991. Enhanced attraction to blood by pigs with inadequate dietary protein supplementation. *Canadian Journal of Animal Science* 71:611-9.
- ¹⁵⁴ Taylor NR, Main DCJ, Mendl M, Edwards SA. 2009. Tail-biting: A new perspective. *The Veterinary Journal* doi:10.1016/j.tvjl.2009.08.028.
- ¹⁵⁵ Jensen P. 2002. Behaviour of pigs. In: Jensen P (ed.), *The Ethology of Domestic Animals: an Introductory Text* (Wallingford, U.K.: CABI Publishing, pp. 159-72).
- ¹⁵⁶ Petersen V. 1994. The development of feeding and investigatory behaviour in free-ranging domestic pigs during their first 18 weeks of life. *Applied Animal Behaviour Science* 42:87-98.
- ¹⁵⁷ Scientific Veterinary Committee. 1997. *The Welfare of Intensively Kept Pigs*, section 2.11. http://ec.europa.eu/food/fs/sc/oldcomm4/out17_en.pdf. Accessed June 2, 2010.
- ¹⁵⁸ Johnson AK, Morrow-Tesch JL, and McGlone JJ. 2001. Behavior and performance of lactating sows and piglets reared indoors or outdoors. *Journal of Animal Science* 79:2571-9.
- ¹⁵⁹ Stolba A and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. *Animal Production* 48:419-25.
- ¹⁶⁰ Petersen V. 1994. The development of feeding and investigatory behaviour in free-ranging domestic pigs during their first 18 weeks of life. *Applied Animal Behaviour Science* 42:87-98.
- ¹⁶¹ Stolba A and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. *Animal Production* 48:419-25.
- ¹⁶² 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.

-
- ¹⁶³ Beattie VE, Walker N, and Sneddon IA. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare* 4:207-20.
- ¹⁶⁴ Beattie VE, Walker N, and Sneddon IA. 1996. An investigation of the effect of environmental enrichment and space allowance on the behaviour and production of growing pigs. *Applied Animal Behaviour Science* 48:151-8.
- ¹⁶⁵ Beattie VE, O'Connell NE, Kilpatrick DJ, and Moss BW. 2000. Influence of environmental enrichment on welfare-related behavioural and physiological parameters in growing pigs. *Animal Science* 70:443-50.
- ¹⁶⁶ Beattie VE, Walker N, and Sneddon IA. 1996. An investigation of the effect of environmental enrichment and space allowance on the behaviour and production of growing pigs. *Applied Animal Behaviour Science* 48:151-8.
- ¹⁶⁷ Fraser D, Phillips PA, Thompson BK, and Tennessen T. 1991. Effect of straw on the behaviour of growing pigs. *Applied Animal Behaviour Science* 30:307-18.
- ¹⁶⁸ McKinnon AJ, Edwards SA, Stephens DB, and Walters DE. 1989. Behaviour of groups of weaner pigs in three different housing systems. *British Veterinary Journal* 145:367-72.
- ¹⁶⁹ Beattie VE, O'Connell NE, Kilpatrick DJ, and Moss BW. 2000. Influence of environmental enrichment on welfare-related behavioural and physiological parameters in growing pigs. *Animal Science* 70:443-50.
- ¹⁷⁰ 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.
- ¹⁷¹ Van de Weerd HA, 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* 80:289-98.
- ¹⁷² Day JEL, Van de Weerd HA, 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.
- ¹⁷³ 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.
- ¹⁷⁴ 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.
- ¹⁷⁵ Beattie VE, Walker N, and Sneddon IA. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare* 4:207-20.
- ¹⁷⁶ Walker PK and Bilkei G. 2006. Tail-biting in outdoor pig production. *The Veterinary Journal* 171:367-9.
- ¹⁷⁷ Smith WJ and Penny RHC. 1998. Tail-biting and tail-docking in pigs. *The Veterinary Record* 142:407-8.
- ¹⁷⁸ Stolba A and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. *Animal Production* 48:419-25.
- ¹⁷⁹ Petersen V. 1994. The development of feeding and investigatory behaviour in free-ranging domestic pigs during their first 18 weeks of life. *Applied Animal Behaviour Science* 42:87-98.
- ¹⁸⁰ Beattie VE, O'Connell NE, Kilpatrick DJ, and Moss BW. 2000. Influence of environmental enrichment on welfare-related behavioural and physiological parameters in growing pigs. *Animal Science* 70:443-50.
- ¹⁸¹ Cox LN and Cooper JJ. 2001. Observations on the pre- and post-weaning behaviour of piglets reared in commercial indoor and outdoor environments. *Animal Science* 72:75-86.
- ¹⁸² De Jonge FH, Bokkers EAM, Schouten WGP, and Helmond FA. 1996. Rearing piglets in a poor environment: developmental aspects of social stress in pigs. *Physiology & Behavior* 60(2):389-96.
- ¹⁸³ 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.
- ¹⁸⁴ Oliveira AFS, Rossi AO, Silva LFR, Lau MC, and Barreto RE. 2010. Play behaviour in nonhuman animals and the animal welfare issue. *Journal of Ethology* 28(1):1-5.
- ¹⁸⁵ Newberry RC and Wood-Gush DGM. 1988. Development of some behaviour patterns in piglets under semi-natural conditions. *Animal Production* 46:103-9.
- ¹⁸⁶ Blackshaw JK, Swain AJ, Blackshaw AW, Thomas FJM, and Gillies KJ. 1997. The development of playful behaviour in piglets from birth to weaning in three farrowing environments. *Applied Animal Behaviour Science* 55:37-49.
- ¹⁸⁷ Johnson AK, Morrow-Tesch JL, and McGlone JJ. 2001. Behavior and performance of lactating sows and piglets reared indoors or outdoors. *Journal of Animal Science* 79:2571-9.

-
- ¹⁸⁸ Lyons CAP, Bruce JM, Fowler VR, and English PR. 1995. A comparison of productivity and welfare of growing pigs in four intensive systems. *Livestock Production Science* 43:265-74.
- ¹⁸⁹ Beattie VE, Walker N, and Sneddon IA. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare* 4:207-20.
- ¹⁹⁰ Beattie VE, Walker N, and Sneddon IA. 1995. Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare* 4:207-20.
- ¹⁹¹ Day JEL, Burfoot A, Docking CM, Whittaker X, Spoolder HAM, and Edwards SA. 2002. The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. *Applied Animal Behaviour Science* 76:189-202.
- ¹⁹² Taylor NR, Main DCJ, Mendl M, Edwards SA. 2009. Tail-biting: A new perspective. *The Veterinary Journal* doi:10.1016/j.tvjl.2009.08.028.
- ¹⁹³ Day JEL, Burfoot A, Docking CM, Whittaker X, Spoolder HAM, and Edwards SA. 2002. The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. *Applied Animal Behaviour Science* 76:189-202.
- ¹⁹⁴ Lyons CAP, Bruce JM, Fowler VR, and English PR. 1995. A comparison of productivity and welfare of growing pigs in four intensive systems. *Livestock Production Science* 43:265-74.
- ¹⁹⁵ Zoric M, Nilsson E, Lundeheim N, and Wallgren P. 2009. Incidence of lameness and abrasions in piglets in identical farrowing pens with four different types of floor. *Acta Veterinaria Scandinavica* 51:23.
- ¹⁹⁶ Hughes BO and Duncan IJH. 1981. Do animals have behavioural needs? *Applied Animal Ethology* 7:381-93.
- ¹⁹⁷ Jensen P and Toates FM. 1993. Who needs 'behavioural needs'? Motivational aspects of the needs of animals. *Applied Animal Behaviour Science* 37:161-81.
- ¹⁹⁸ Puppe B, Meunier-Salaun MC, Otten W, and Orgeur P. 2008. The welfare of piglets. In: Faucitano L and Schaefer AL (eds.), *Welfare of Pigs from Birth to Slaughter* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 97-131).
- ¹⁹⁹ Wathes CM. 2001. Aerial pollutants from weaner production. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 259-71).
- ²⁰⁰ 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.
- ²⁰¹ 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.
- ²⁰² Wathes CM. 2001. Aerial pollutants from weaner production. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 259-71).
- ²⁰³ Robertson JF, Wilson D, and Smith WJ. 1990. Atrophic rhinitis: the influence of the aerial environment. *Animal Production* 50:173-82.
- ²⁰⁴ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 303-4).
- ²⁰⁵ Robertson JF, Wilson D, and Smith WJ. 1990. Atrophic rhinitis: the influence of the aerial environment. *Animal Production* 50:173-82.
- ²⁰⁶ Wathes CM. 2001. Aerial pollutants from weaner production. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 259-71).
- ²⁰⁷ Stalder K. 2007. Piglet survival – a key performance indicator. *National Hog Farmer*, May 15, pp. 40-2.
- ²⁰⁸ U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services, National Animal Health Monitoring System. 2007. *Swine 2006, Part I: Reference of swine health and management practices in the United States*, p. 20. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/swine2006/Swine2006_PartI.pdf. Accessed October 17, 2008.
- ²⁰⁹ Illmann G, Neuhauserová K, Pokorná Z, Chaloupková H, and Šimečková M. 2008. Maternal responsiveness of sows toward piglet's screams during the first 24 h postpartum. *Applied Animal Behaviour Science* 112:248-59.
- ²¹⁰ Houpt KA. 2005. *Domestic Animal Behavior*, 4th Edition (Ames, IA: Blackwell Publishing, p.188).
- ²¹¹ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 80).

-
- ²¹² Weary DM, Pajor EA, Fraser D, and Honkanen AM. 1996. Sow body movements that crush piglets: a comparison between two types of farrowing accommodation. *Applied Animal Behaviour Science* 49:149-58.
- ²¹³ 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).
- ²¹⁴ Le Dividich J, Martineau GP, Madec F, and Orgeur P. 2003. Saving and rearing underprivileged and supernumerary piglets, and improving their health at weaning. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 361-83).
- ²¹⁵ Grandinson K, Lund MS, Rydhmer L, and Strandberg E. 2002. Genetic parameters for the piglet mortality traits crushing, stillbirth and total mortality, and their relation to birth weight. *Acta Agriculturae Scandinavica Section A: Animal Science* 52:167-73.
- ²¹⁶ Le Dividich J, Martineau GP, Madec F, and Orgeur P. 2003. Saving and rearing underprivileged and supernumerary piglets, and improving their health at weaning. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 361-83).
- ²¹⁷ Lund MS, Puonti M, Rydhmer L, and Jensen J. 2002. Relationship between litter size and perinatal and pre-weaning survival in pigs. *Animal Science* 74:217-22.
- ²¹⁸ Spicer EM, Driesen SJ, Fahy VA, et al. 1986. Causes of preweaning mortality on a large intensive piggery. *Australian Veterinary Journal* 63(3):71-5.
- ²¹⁹ Dyck GW and Swierstra EE. 1987. Causes of piglet death from birth to weaning. *Canadian Journal of Animal Science* 67:543-7.
- ²²⁰ 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.
- ²²¹ U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services, National Animal Health Monitoring System. 1992. Preweaning morbidity and mortality: national swine survey. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/NSS92/nss92_is_Preweaning.pdf. Accessed June 2, 2010.
- ²²² Puppe B, Meunier-Salaun MC, Otten W, and Orgeur P. 2008. The welfare of piglets. In: Faucitano L and Schaefer AL (eds.), *Welfare of Pigs from Birth to Slaughter* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 97-131).
- ²²³ U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services, National Animal Health Monitoring System. 2008. Swine 2006, Part IV: Changes in the U.S. Pork Industry, 1990-2006, p. 21. www.aphis.usda.gov/vs/ceah/ncahs/nahms/swine/swine2006/Swine2006_PartIV.pdf. Accessed June 2, 2010.
- ²²⁴ Puppe B, Meunier-Salaun MC, Otten W, and Orgeur P. 2008. The welfare of piglets. In: Faucitano L and Schaefer AL (eds.), *Welfare of Pigs from Birth to Slaughter* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 97-131).
- ²²⁵ Waddell J. 1996. Management accounts for most deaths. *National Hog Farmer*, Spring, pp. 12-17.
- ²²⁶ Fraser D, Phillips PA, Thompson BK, Pajor EA, Weary DM, and Braithwaite LA. 1995. Behavioural aspects of piglet survival and growth. In: Varley MA (ed.), *The Neonatal Pig: Development and Survival* (Wallingford, U.K.: CABI Publishing, pp. 287-312).
- ²²⁷ Holyoake PK, Dial GD, Trigg T, and King VL. 1995. Reducing pig mortality through supervision during the perinatal period. *Journal of Animal Science* 73:3543-51.
- ²²⁸ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 267).
- ²²⁹ White KR, Anderson DM, and Bate LA. 1996. Increasing piglet survival through an improved farrowing management protocol. *Canadian Journal of Animal Science* 76(4):491-5.
- ²³⁰ White KR, Anderson DM, and Bate LA. 1996. Increasing piglet survival through an improved farrowing management protocol. *Canadian Journal of Animal Science* 76(4):491-5.
- ²³¹ Scientific Veterinary Committee. 1997. *The Welfare of Intensively Kept Pigs*, section 5.3.1. http://ec.europa.eu/food/fs/sc/oldcomm4/out17_en.pdf. Accessed June 2, 2010.

-
- ²³² Hutson GD, Wilkinson JL, and Luxford BG. 1991. The response of lactating sows to tactile, visual and auditory stimuli associated with a model piglet. *Applied Animal Behaviour Science* 32:129-137.
- ²³³ Jarvis S, D'Eath RB, and Fujita K. 2005. Consistency of piglet crushing by sows. *Animal Welfare* 14:43-51.
- ²³⁴ Wechsler B and Weber R. 2007. Loose farrowing systems: challenges and solutions. *Animal Welfare* 16:295-307.
- ²³⁵ Jarvis S, D'Eath RB, and Fujita K. 2005. Consistency of piglet crushing by sows. *Animal Welfare* 14:43-51.
- ²³⁶ Blackshaw JK, Blackshaw AW, Thomas FJ, and Newman FW. 1994. Comparison of behaviour patterns of sows and litters in a farrowing crate and a farrowing pen. *Applied Animal Behaviour Science* 39:281-295.
- ²³⁷ Robertson JB, Laird R, Hall JKS, Forsyth RJ, Thomson JM, and Walker-Love J. 1966. A comparison of two indoor farrowing systems for sows. *Animal Production* 8:171-8.
- ²³⁸ Marchant JN, Rudd AR, Mendl MT, et al. 2000. Timing and causes of piglet mortality in alternative and conventional farrowing systems. *Veterinary Record* 147:209-14.
- ²³⁹ Weber R, Keil NM, Fehr M, and Horat R. 2007. Piglet mortality on farms using farrowing systems with or without crates. *Animal Welfare* 16:277-9.
- ²⁴⁰ Lou Z and Hurnik JF. 1994. An ellipsoid farrowing crate: it's ergonomical design and effects on pig productivity. *Journal of Animal Science* 72:2610-6.
- ²⁴¹ McGlone JJ and Morrow-Tesch J. 1990. Productivity and behavior of sows in level vs sloped farrowing pens and crates. *Journal of Animal Science* 68:82-7.
- ²⁴² Collins ER, Kornegay ET, Bonnette ED. 1987. The effects of two confinements systems on the performance of nursing sows and their litters. *Applied Animal Behaviour Science* 17:51-9.
- ²⁴³ Honeyman MS, Roush WB, and Penner AD. 1999. Piglet mortality in various hut types for outdoor farrowing. ASL-R1680. Swine Research Report AS-642. (Ames, IA: ISU Extension Service). www.ipic.iastate.edu/reports/99swinereports/asl-1680.pdf. Accessed June 2, 2010.
- ²⁴⁴ McGlone JJ and Hicks TA. 2000. Farrowing hut design and sow genotype (Camborough-15 vs 25% Meishan) effects on outdoor sow and litter productivity. *Journal of Animal Science* 78:2832-5.
- ²⁴⁵ Bøe K. 1991. The process of weaning in pigs: when the sow decides. *Applied Animal Behaviour Science* 30:47-59.
- ²⁴⁶ Petersen V. 1994. The development of feeding and investigatory behaviour in free-ranging domestic pigs during their first 18 weeks of life. *Applied Animal Behaviour Science* 42:87-98.
- ²⁴⁷ Worobec EK, Duncan IJH, Widowski TM. 1999. The effects of weaning at 7, 14 and 28 days on piglet behaviour. *Applied Animal Behaviour Science* 62:173-82.
- ²⁴⁸ Newberry RC and Wood-Gush DGM. 1985. The suckling behaviour of domestic pigs in a semi-natural environment. *Behaviour* 95:11-25.
- ²⁴⁹ Jensen P and Recén B. 1989. When to wean – observations from free-ranging domestic pigs. *Applied Animal Behaviour Science* 23:49-60.
- ²⁵⁰ Stolba A, and Wood-Gush DGM. 1989. The behaviour of pigs in a semi-natural environment. *Animal Production* 48:419-25.
- ²⁵¹ Petersen V. 1994. The development of feeding and investigatory behaviour in free-ranging domestic pigs during their first 18 weeks of life. *Applied Animal Behaviour Science* 42:87-98.
- ²⁵² Jensen P. 1988. Maternal behaviour and mother-young interactions during lactation in free-ranging domestic pigs. *Applied Animal Behaviour Science* 20:297-308.
- ²⁵³ Jensen P and Stangel G. 1992. Behaviour of piglets during weaning in a semi-natural enclosure. *Applied Animal Behaviour Science* 33:227-38.
- ²⁵⁴ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 359, 366).
- ²⁵⁵ 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. 247).
- ²⁵⁶ Stalder K. 2007. Piglet survival – a key performance indicator. *National Hog Farmer*, May 15, pp. 40-2.
- ²⁵⁷ Scientific Veterinary Committee. 1997. *The Welfare of Intensively Kept Pigs*, section 5.3. http://ec.europa.eu/food/fs/sc/oldcomm4/out17_en.pdf. Accessed June 2, 2010.
- ²⁵⁸ Hill H. 1994. Segregated early weaning unfolds. *National Hog Farmer*, Fall, pp. 6-7, 10.

-
- ²⁵⁹ Worobec EK, Duncan IJH, Widowski TM. 1999. The effects of weaning at 7, 14 and 28 days on piglet behaviour. *Applied Animal Behaviour Science* 62:173-82.
- ²⁶⁰ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, pp. 396-7).
- ²⁶¹ Jensen P and Stangel G. 1992. Behaviour of piglets during weaning in a semi-natural enclosure. *Applied Animal Behaviour Science* 33:227-38.
- ²⁶² Puppe B, Meunier-Salaun MC, Otten W, and Orgeur P. 2008. The welfare of piglets. In: Faucitano L and Schaefer AL (eds.), *Welfare of Pigs from Birth to Slaughter* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 97-131).
- ²⁶³ 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).
- ²⁶⁴ King RH and Pluske JR. 2003. Nutritional management of the pig in preparation for weaning. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 37-51).
- ²⁶⁵ Weary DM, Jasper J, and Hötzel MJ. 2008. Understanding weaning distress. *Applied Animal Behaviour Science* 110:24-41.
- ²⁶⁶ Petersen V. 1994. The development of feeding and investigatory behaviour in free-ranging domestic pigs during their first 18 weeks of life. *Applied Animal Behaviour Science* 42:87-98.
- ²⁶⁷ Held S and Mendl M. 2001. Behaviour of the young weaner pig. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 273-97).
- ²⁶⁸ Held S and Mendl M. 2001. Behaviour of the young weaner pig. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 273-97).
- ²⁶⁹ Weary DM and Fraser D. 1997. Vocal response of piglets to weaning: effect of piglet age. *Applied Animal Behaviour Science* 54:153-60.
- ²⁷⁰ Weary DM and Fraser D. 1995. Calling by domestic piglets: reliable signals of need? *Animal Behaviour* 50:1047-55.
- ²⁷¹ Weary DM and Fraser D. 1997. Vocal response of piglets to weaning: effect of piglet age. *Applied Animal Behaviour Science* 54:153-60.
- ²⁷² Weary DM and Fraser D. 1995. Calling by domestic piglets: reliable signals of need? *Animal Behaviour* 50:1047-55.
- ²⁷³ Weary DM, Lawson GL, and Thompson BK. 1996. Sows show stronger responses to isolation calls of piglets associated with greater levels of piglet need. *Animal Behaviour* 52:1247-53.
- ²⁷⁴ Fraser D. 1978. Observations on the behavioural development of suckling and early-weaned piglets during the first six weeks after birth. *Animal Behaviour* 26:22-30.
- ²⁷⁵ Widowski TA, Torrey S, Bench CJ, Gonyou HW. 2008. Development of ingestive behaviour and the relationship to belly nosing in early-weaned piglets. *Applied Animal Behaviour Science* 110:109-27.
- ²⁷⁶ Pluske JR, Le Dividich J, and Verstegen MWA. 2003. *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, p. 15).
- ²⁷⁷ Fraser D. 1978. Observations on the behavioural development of suckling and early-weaned piglets during the first six weeks after birth. *Animal Behaviour* 26:22-30.
- ²⁷⁸ 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).
- ²⁷⁹ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 263).
- ²⁸⁰ 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).
- ²⁸¹ Holden PJ and Ensminger ME. 2006. *Swine Science*, 7th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 368).

-
- ²⁸² 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, IA: Blackwell Publishing, pp. 149-77).
- ²⁸³ Drum SD, Walker RD, Marsh WE, Mellencamp MM, and King VL. 1998. Growth performance of segregated early-weaned versus conventionally weaned pigs through finishing. *Swine Health and Production* 6(5):203-10.
- ²⁸⁴ Metz JHM and Gonyou HW. 1990. Effect of age and housing conditions on the behavioural and haemolytic reaction of piglets to weaning. *Applied Animal Behaviour Science* 27:299-309.
- ²⁸⁵ Miller HM and Slade RD. 2003. Digestive physiology of the weaned pig. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 117-44).
- ²⁸⁶ Bøe K. 1991. The process of weaning in pigs: when the sow decides. *Applied Animal Behaviour Science* 30:47-59.
- ²⁸⁷ Bark LJ, Crenshaw TD, and Leibbrandt VD. 1986. The effect of meal intervals and weaning on feed intake of early weaned pigs. *Journal of Animal Science* 62:1233-9.
- ²⁸⁸ Mormède P and Hay M. 2003. Behavioural changes and adaptations associated with weaning. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 53-60).
- ²⁸⁹ Bailey M, Vega-Lopez MA, Rothkötter HJ, Haverson K, Bland PW, Miller BG, and Stokes CR. 2001. Enteric immunity and gut health. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 207-22).
- ²⁹⁰ Miller HM and Slade RD. 2003. Digestive physiology of the weaned pig. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 117-44).
- ²⁹¹ Dunshea FR. 2003. Metabolic and endocrine changes around weaning. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 61-80).
- ²⁹² McCracken BA, Spurlock ME, Roos MA, Zuckermann FA, and Gaskins HR. 1999. Weaning anorexia may contribute to local inflammation in the piglet small intestine. *Journal of Nutrition* 129:613-9.
- ²⁹³ Lackeyram D, Yang C, Archbold T, Swanson KC, and Fan MZ. 2010. Early weaning reduces small intestinal alkaline phosphatase expression in pigs. *The Journal of Nutrition* 140:461-8.
- ²⁹⁴ Kelly D and King TP. 2001. Digestive physiology and development in pigs. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 179-206).
- ²⁹⁵ 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).
- ²⁹⁶ Bailey M, Vega-Lopez MA, Rothkötter HJ, Haverson K, Bland PW, Miller BG, and Stokes CR. 2001. Enteric immunity and gut health. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 207-22).
- ²⁹⁷ Worobec EK, Duncan IJH, Widowski TM. 1999. The effects of weaning at 7, 14 and 28 days on piglet behaviour. *Applied Animal Behaviour Science* 62:173-82.
- ²⁹⁸ Metz JHM and Gonyou HW. 1990. Effect of age and housing conditions on the behavioural and haemolytic reaction of piglets to weaning. *Applied Animal Behaviour Science* 27:299-309.
- ²⁹⁹ Dunshea FR. 2003. Metabolic and endocrine changes around weaning. In: Pluske JR, Le Dividich J, and Verstegen MWA (eds.), *Weaning the Pig: Concepts and Consequences* (Wageningen, The Netherlands: Wageningen Academic Publishers, pp. 61-80).
- ³⁰⁰ Worsaae H and Schmidt M. 1980. Plasma cortisol and behaviour in early weaned piglets. *Acta Veterinaria Scandinavica* 21(4):640-57.
- ³⁰¹ Weary DM, Pajor EA, Bonenfant M, Ross SK, Fraser D, and Kramer DL. 1999. Alternative housing for sows and litters: 2. Effects of a communal piglet area on pre- and post-weaning behaviour and performance. *Applied Animal Behaviour Science* 65:123-35.
- ³⁰² Held S and Mendl M. 2001. Behaviour of the young weaner pig. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 273-97).

-
- ³⁰³ Fraser D. 1978. Observations on the behavioural development of suckling and early-weaned piglets during the first six weeks after birth. *Animal Behaviour* 26:22-30.
- ³⁰⁴ Jarvis S, Moinard C, Robson SK, et al. 2008. Effects of weaning age on the behavioural and neuroendocrine development of piglets. *Applied Animal Behaviour Science* 110:166-81.
- ³⁰⁵ Luescher UA, Friendship RM, Lissemore KD, and McKeown DB. 1989. Clinical ethology in food animal practice. *Applied Animal Behaviour Science* 22:191-214.
- ³⁰⁶ Gonyou HW, Beltranena E, Whittington DL, and Patience JF. 1998. The behaviour of pigs weaned at 12 and 21 days of age from weaning to market. *Canadian Journal of Animal Science* 78:517-23.
- ³⁰⁷ Blackshaw JK. 1981. Some behavioural deviations in weaned domestic pigs: persistent inguinal nose thrusting, and tail and ear biting. *Animal Production* 33:325-32.
- ³⁰⁸ Latham NR and Mason GJ. 2008. Maternal deprivation and the development of stereotypic behaviour. *Applied Animal Behaviour Science* 110:84-108.
- ³⁰⁹ Metz JHM and Gonyou HW. 1990. Effect of age and housing conditions on the behavioural and haemolytic reaction of piglets to weaning. *Applied Animal Behaviour Science* 27:299-309.
- ³¹⁰ Held S and Mendl M. 2001. Behaviour of the young weaner pig. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 273-97).
- ³¹¹ Van Putten G and Dammers J. 1976. A comparative study of the well-being of piglets reared conventionally and in cages. *Applied Animal Ethology* 2:339-56.
- ³¹² Metz JHM and Gonyou HW. 1990. Effect of age and housing conditions on the behavioural and haemolytic reaction of piglets to weaning. *Applied Animal Behaviour Science* 27:299-309.
- ³¹³ Widowski TA, Torrey S, Bench CJ, Gonyou HW. 2008. Development of ingestive behaviour and the relationship to belly nosing in early-weaned piglets. *Applied Animal Behaviour Science* 110:109-27.
- ³¹⁴ Worobec EK, Duncan IJH, Widowski TM. 1999. The effects of weaning at 7, 14 and 28 days on piglet behaviour. *Applied Animal Behaviour Science* 62:173-82.
- ³¹⁵ Fraser D. 1978. Observations on the behavioural development of suckling and early-weaned piglets during the first six weeks after birth. *Animal Behaviour* 26:22-30.
- ³¹⁶ Gonyou HW, Beltranena E, Whittington DL, and Patience JF. 1998. The behaviour of pigs weaned at 12 and 21 days of age from weaning to market. *Canadian Journal of Animal Science* 78:517-23.
- ³¹⁷ Held S and Mendl M. 2001. Behaviour of the young weaner pig. In: Varley MA and Wiseman J (eds.), *The Weaner Pig: Nutrition and Management* (Wallingford, U.K.: CABI Publishing, pp. 273-97).
- ³¹⁸ Poletto R, Steibel JP, Siegford JM, and Zanella AJ. 2006. Effects of early weaning and social isolation on the expression of glucocorticoid and mineralocorticoid receptor and 11 β -hydroxysteroid dehydrogenase 1 and 2 mRNAs in the frontal cortex and hippocampus of piglets. *Brain Research* 1067:36-42.
- ³¹⁹ Mirescu C, Peters JD, and Gould E. 2004. Early life experience alters response of adult neurogenesis to stress. *Nature Neuroscience* 7(8):841-6.
- ³²⁰ Sánchez MM, Ladd CO, and Plotsky PM. 2001. Early adverse experience as a developmental risk factor for later psychopathology: Evidence from rodent and primate models. *Development and Psychopathology* 13:419-49.
- ³²¹ Latham NR and Mason GJ. 2008. Maternal deprivation and the development of stereotypic behaviour. *Applied Animal Behaviour Science* 110:84-108.
- ³²² Poletto R, Steibel JP, Siegford JM, and Zanella AJ. 2006. Effects of early weaning and social isolation on the expression of glucocorticoid and mineralocorticoid receptor and 11 β -hydroxysteroid dehydrogenase 1 and 2 mRNAs in the frontal cortex and hippocampus of piglets. *Brain Research* 1067:36-42.
- ³²³ 2002. Animal Welfare Resolution, National Pork Board, January. www.pork.org/PorkScience/Documents/WELFAREFACT-wlfare%20resolut.pdf. Accessed June 2, 2010.
- ³²⁴ Van Putten G and Dammers J. 1976. A comparative study of the well-being of piglets reared conventionally and in cages. *Applied Animal Ethology* 2:339-56.