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A critical reflection on intensive pork production with an emphasis on animal health and welfare

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Introduction

Domestication is the process by which a population of animals becomes adapted to man and to the captive environment by genetic changes and environmentally induced developmental events recurring during each generation (Cronin et al., 2014). Originally, domesticated livestock was mainly farmed extensively. The main impetus for more intensive animal production occurred after the Second World War when governments developed policies to provide sufficient, safe, and cheap food to the population. At the same time, farmers had to increase productivity to meet rising costs (Niesten et al., 2003), and this could be achieved through intensive production. Improved animal nutrition, feed efficiency, health management, environmental control, reproduction management, genetic selection for better performance, and consistency of product quality and delivery to the marketplace have been the main objectives in the development of intensive livestock production.

Since the 1960s, however, increased animal welfare concerns have been raised regarding intensive livestock production. In 1965, the Brambell Report in the UK commented adversely on the tethering of animals, overstocking and close confinement, the use of slatted flooring, and poor lighting and ventilation for animals (Brambell, 1965). Since then, other welfare concerns have been raised, including the imposition of painful husbandry procedures (e.g., tail docking and castration), the restriction of natural behavior and the reduction in complexity of the animals' environment (Broom and Fraser, 2015).

Pig production is one of the most important livestock sectors globally. Pork accounts for more than one-quarter of total protein consumed worldwide and for ~35% of all meat production (Bruinsma, 2003; FAO, 2017). The demand for meat and animal protein will likely further increase, firstly because the world population is expected to grow further and secondly because, in low- and middle-income countries, more people are expected to have higher incomes that enable meat consumption (United Nations, 2019). In high-income countries, most of the pigs are raised under intensive conditions. In some farms, piglets may be reared in outdoor systems along with the sow, but postweaned pigs are almost always kept in indoor systems (EFSA, 2007).

Intensive pig production is characterized by a high biological and economic productivity with a simultaneously low input of labor, feed, and space per animal. As a rule, this results in bigger herds with a large number of livestock indoors, specialization, and standardized management procedures within a farm. Intensive pig production often takes place in geographically segregated areas, batch production (all-in-all-out) is often used for raising pigs postweaning and there is a specialization of labor, with larger companies often employing their own veterinarians, nutritionists, and/or reproductive physiologists. The benefits are increased competitiveness, potential reduction of environmental impact (due to the increased productivity), and the possibility of stringent quality management of the entire production process. On the other hand, there is public perception that intensive pig production systems raise concerns about animal welfare, naturalness, and use of antimicrobials

(Clarke et al., 2019). Animal health issues are rarely considered explicitly by consumers.

The present paper provides a critical reflection on intensive pork production. Although some outdoor systems may also adopt intensive management practices, the term intensive production in the present paper refers to systems where the pigs are housed in confinement indoors. Emphasis is placed on animal health and welfare. So far, the focus in the literature has been directed toward animal welfare, without considering the health aspects. Where appropriate and data are available, comparisons are made with (semi-) extensive systems.

Animal Health

Health has been defined as the ability to adapt and manage physical, mental, and social challenges throughout life (Hubert et al., 2011). In this sense, animal health is a prerequisite to realize the genetic potential of animals. In pig production, health as defined above is usually not directly measured. Instead, the presence of disease or pathogenic infections or the amount of therapeutic medicine use is measured, or else, the quality of the management or the level of biosecurity of pig farms. Diseases may result in direct losses through mortality, loss of productivity, trade restrictions, reduced market value, and often food insecurity (Dehove et al., 2012). Therefore, poor health is considered as a major constraint to swine production. Impaired health may be the result of infectious diseases (endemic, epidemic, and zoonoses), production disorders, and environmental contaminants (Table 1). In modern production systems, the cause of reduced health is generally multifactorial.

Endemic Diseases

During the last decades, pig health has not paralleled the increases in litter size or improvements in finishing pig performance (Tani et al., 2018). Many pig herds worldwide are endemically infected with important respiratory, intestinal, and systemic pathogens (Holtkamp et al., 2007), e.g., porcine reproductive and respiratory syndrome virus (**PRRSV**), porcine circovirus type 2, *Mycoplasma hyopneumoniae*, influenza A virus in swine (**IAV-S**), pathogenic *Escherichia coli* strains, *Lawsonia intracellularis*, *Brachyspira* spp., and *Streptococcus* spp. It is not only the presence or prevalence of pathogens which is important, as the nature of the disease that they cause can also depend on the production conditions. For example, PRRSV and IAV-S are two major pathogens for which the epidemiology and clinical course of the infection are linked with the type of production. Losses due to PRRS are especially important in large farms, whereas IAV-S is a multi-species pathogen (including humans) for which the emergence of multiple variants has coincided with the intensification of production (Van Reeth and Vincent, 2019). Lung lesions, such as from pneumonia and pleurisy, are common in pigs at slaughter, with prevalences ranging between 10% and 50% (Meyns et al., 2011; Merialdi et al., 2012). These are comparable to the prevalences obtained decades ago (Christensen and Cullinane, 1990). Furthermore, clinical diarrhea still commonly occurs in pig herds (Weber et al., 2015), despite the frequent use of antimicrobials (Sarrazin et al., 2019).

Different factors might explain these high prevalences. First, possible sources of infection and transmission routes are numerous, e.g., sow-to-piglet, pig-to-pig, via semen, aerosols, airborne transmission in pig dense areas, people, rodents, insects, domestic and feral non-swine animals, birds, fomites, carcasses, and vehicles (Filippitzi et al., 2018). Second, often a large number of animals share the same airspace or are raised at the same location, with a high stocking density facilitating the transmission of pathogens. Third, because of the segregation of different production phases (breeding, raising, and finishing), pigs may be transported over longer distances, inducing stress and facilitating pathogen transmission.

Nonetheless, it is often difficult to draw direct links between the intensification of pig production and the high prevalence of endemic diseases. Endemic diseases generally result from an interaction of different infectious agents and are influenced by environmental, nutritional, and management conditions. Consequently, most of them are multifactorial, with the clinical outcome, the severity of lesions, and economic losses being the result of interactions between many factors.

In fact, pigs can become sick from the same diseases regardless of the production system. In intensive confined systems, there might be a higher incidence of respiratory and digestive diseases than in outdoor systems, mainly because of higher stocking densities and in situations of poor ventilation,

Table 1. General evaluation of animal health parameters in intensive pig production systems

	Critical items	Comments
Endemic diseases	High (herd) prevalence of pathogenic infections	Mostly subclinical
	High (herd) prevalence of lesions in slaughter pigs (lungs, stomach, etc.)	Mostly subclinical
Epidemic diseases	Risk for infection in pathogen-free herds	Most herds remain free from infection
	Risk for infection by wild pigs	Good external biosecurity and hygiene
Foodborne zoonoses	Important bacterial pathogens, e.g., *Salmonella* still present on many farms	Mostly subclinical
	Low level of parasitic pathogens	Substantial reduction, very low risk
Non-foodborne zoonoses	Stockpersons often in contact with many animals	Contact not intense
Antimicrobial use	Total use too high, also for metaphylaxis and prophylaxis, use of critically important molecules	Positive evolutions, implementation of alternatives
Environmental contaminants	Via the feed or drinking water; if present, large number of affected animals	Very low risk: quality of feed and drinking water, controlled environment
Production diseases	High piglet mortality	Similar levels as in extensive systems
	Health problems post-weaning: early weaning, low weaning weight	Environmental control, optimal nutrition and management
	Locomotion problems: (inappropriate) slatted floors, insufficient bedding material, poor management	Optimization of management and housing conditions

giving higher concentrations of air pollutants (dust and stable gases). However, in outdoor systems, pigs are at higher risk for parasitic infections (Roepstorff and Nansen, 1994) or diseases like brucellosis and leptospirosis, for which contact with wild boar or a contaminated environment are important for transmission (Salajpal et al., 2013).

Alban et al. (2015) analyzed data from a large Danish abattoir, slaughtering organic, free range (where both sows and slaughter pigs are given access to range), and "conventionally" raised (i.e., from intensive production systems) finishing pigs. A total of 13 lesion types were more frequent among organic/free-range pigs than among pigs from intensive farms—among others old fractures, tail lesions, and osteomyelitis. Four lesion types were equally frequent in the two groups: chronic pneumonia, chronic pleurisy, fresh fracture, and abscess in head/ear. Four lesion types were recorded less frequently among organic/free-range pigs compared with pigs from intensive farms, namely abscess in leg/toe, hernia, and scar/hock lesion. In a subsequent study covering 3 yr of data collection, similar results were obtained, i.e., higher risk for more lesions in pigs from organic and free-range systems (Kongsted and Sörensen, 2017). These results contradict the perception that endemic diseases or lesions are more prevalent in intensive systems.

Epidemic Diseases

Epidemic diseases, often termed transboundary animal diseases, can cause high morbidity and mortality in susceptible animal populations and have the potential for serious socio-economic consequences. Examples include African swine fever, classical swine fever, vesicular diseases (e.g., foot and mouth disease), and Aujeszky's disease (VanderWaal and Deen, 2018). In some parts of the world, wild pigs have been identified as an important disease reservoir (VanderWaal and Deen, 2018). They represent a permanent risk for domestic pig populations in regions that are free from the disease. Although the intensification and globalization of pig production can contribute to the emergence and global spread of these diseases, driven in part by frequent movements of pigs, feed, and pork products, both external biosecurity (e.g., no contact with wild pigs) and hygiene procedures are much more difficult to implement in extensive and outdoor systems. As a consequence, backyard and/or outdoor production systems prove to be more vulnerable with regard to epidemic diseases such as African swine fever.

Foodborne Zoonoses

Important foodborne bacterial pathogens in pigs include *Salmonella*, *Yersinia enterocolitica*, *Toxoplasma gondii*, and *Campylobacter* spp. Human salmonellosis is the second most reported zoonosis in the EU, with 41.5% of the human cases being attributable to pigs (EFSA and ECDC, 2018). The risk of foodborne parasites such as *Taenia solium*, *Trichinella spiralis*, and to a lesser extent *T. gondii* has decreased to low levels in intensive pig production systems in the United States (Davies, 2011) and the EU (EFSA, 2018).

Unfortunately, there is sparse research directly comparing the risk of foodborne zoonoses in confined (or intensive) and nonconfined (or less intensive) production of pigs. Reported prevalences of *Salmonella* in modern pork industries in high-income countries compare favorably with those reported in studies of (1) wild pig populations, (2) high-income countries before intensification of production, and (3) recent studies from low- and middle-income countries with largely traditional industries (Davies, 2011). Available evidence does not support the hypothesis that intensive pork production has increased the risk for the major bacterial foodborne pathogens in pigs, or that pigs produced in alternative systems are at reduced risk. On the contrary, pigs raised in extensive systems inherently confront higher risks of exposure to foodborne parasites (Davies, 2011). In line with this, Cano-Terriza et al. (2018) found high herd prevalences of the *Mycobacterium tuberculosis* complex among Iberian pigs raised in extensively managed pig farms, sharing their habitat with other domestic and wild species. In addition, Lopez-Lopez et al. (2018) and Rutjes et al. (2014) found a significantly higher risk for hepatitis E (HEV) virus infection in pigs reared in extensive or organic farms than in pigs raised under intensive conditions. The authors suggested that this may be due to higher exposure to pig manure, increasing the transmission rate. Based on the literature, it is clear that pork safety in modern intensive farms has improved demonstrably over recent decades.

Nonfoodborne Zoonoses

Swine influenza virus has emerged as a nonfoodborne zoonotic agent in previous years, but also new pathogens such as methicillin-resistant *Staphylococcus aureus*, *Clostridium difficile*, *Streptococcus suis*, and some others have implicated swine as a potential vehicle for transmission to humans (Angjelovski and Dovenski, 2013). Most of the human infections associated with intensive systems occur in individuals with occupational contact with swine, such as veterinarians, butchers, and farmers. These infections can also occur in extensive systems when sanitation measures are poor and/or people live in close contact with pigs.

Production Diseases

Production diseases can be defined as diseases which persist in intensive systems and whose prevalence or severity tends to increase with the intensity of production. Nutrition, genetics, housing, and/or management are important factors in their expression (Nir, 2003). Production diseases are often multifactorial and appear at the same stage of lactation or reproductive cycle. Typical examples in intensive pig production systems are neonatal piglet mortality, problems in piglets postweaning and locomotion problems.

Neonatal Piglet Mortality

The strong genetic selection for more prolific sows during the last decades has significantly increased litter size, but it has also had several downsides, such as more stillborn piglets, lower birth weight, longer farrowing duration, less colostrum per pig, more competition between littermates, and higher piglet mortality (Theil et al., 2014; Declerck et al., 2016). Neonatal mortality in intensive systems may be more than 20% in some farms (Chantziaras et al., 2018). However, similar piglet mortality percentages have been found in organic pig farms (Rangstrup-Christensen et al., 2018).

Problems Postweaning

Under natural conditions, piglets are weaned at 3 to 4 mo of age and it is a gradual process (Broom and Fraser, 2015). In intensive systems, piglets are often weaned between 3 and 4 wk of age, or even at a younger age. It is an abrupt process with many stressors occurring at the same time, e.g., separation from the sow, different housing, different feed, and different pen-mates. Therefore, it is considered as one of the most critical and stressful periods in the life of piglets (Martínez-Miró et al., 2016). This can affect animal welfare and contribute to health and production problems after weaning, with digestive problems in the postweaning period being a major reason for antimicrobial use in early-weaned piglets (Postma et al., 2016). Although early weaning (<3 wk) can reduce transmission of some pathogens from the sow to the offspring (Mészáros et al., 1985), this is not allowed in the EU except in special circumstances (Directive 2008/120/EC).

In organic production systems, piglets are usually weaned at an older age, at least 6 wk. At that age, piglets are heavier and have a higher intake of dry feed, making the weaning process less stressful than for piglets weaned at 3 to 4 wk of age (Huting et al., 2019).

Locomotion Problems

Group housing of pregnant sows allows the animals to express normal activity and behavior. However, the prevalence of lameness in systems with slatted floors is higher in sows housed in groups than in sows housed individually. Prevalence rates ranging from 6% to 17% have been reported (Pluym et al., 2013). Critical areas for physical injuries in all production stages in intensive systems include skin lesions and locomotion problems, mainly due to inappropriate, poorly maintained and/or slippery flooring (Kilbride et al., 2008). Leg injuries are more likely to occur on concrete, barren, or fully slatted floors than on straw-bedded floors. However, many other factors such as high stocking density, genetics, and body condition influence the risk of injury. The genetic selection for high lean tissue growth rate has increased the risk of degenerative joint diseases, such as osteochondrosis, in fast-growing young animals (Busch and Wachmann, 2011), while the high metabolic demands of lactation can lead to bone mineral mobilization, reduced bone strength, and greater risk of postweaning injury. The prevalence of osteochondrosis has increased from 6.7% in 1970 (Grøndalen, 1981) to ~14% in 2015 (Etterlin et al., 2015).

Antimicrobial Use and Resistance

Antimicrobials are commonly used in intensive pig production systems, not only for treatment but also for metaphylaxis, prophylaxis, and in some countries still for improvement of feed efficiency and growth (Lekagul et al., 2019; Sarrazin et al., 2019). The latter study reported treatment incidences, defined as the number of animals per 100 treated daily, based on group treatment data from nine European countries. Therefore, the treatment incidence can be seen as the percentage of the lifetime, in a certain production stage, that a pig is treated with antimicrobials. When combining the different production stages, the median treatment incidence was 9.2 for a standardized rearing period of 200 d. They found major differences between farms, and 70% of the treatments were applied to weaners. The use of antibiotics for growth promotion has been banned in the EU since 2006 (Regulation (EC) No 1831/2003 of the European Parliament and of the Council on additives for use in animal nutrition). In contrast, other large livestock producing and exporting countries do not (yet) prohibit the use of antibiotics for growth promotion (Li et al., 2017).

Strong indications exist for animal–human transmission of antimicrobial resistance (Scott et al., 2018), and for antimicrobial usage as the strongest driver for selection of resistance (Chantziaras et al., 2014). In a study by Thakur et al. (2005), the frequency of resistance to tetracycline and erythromycin was significantly lower among *Campylobacter coli* isolates from pigs raised in antibiotic-free (ABF) herds. Similar results were found by Gebreyes et al. (2006) with *Salmonella* isolates from pigs raised in ABF systems. Galán-Relaño et al. (2019) found a lower genetic diversity of *Trueperella pyogenes* isolates obtained from pigs raised in intensive production systems in Spain compared with isolates from pigs under extensive conditions. These data suggest that the antimicrobial susceptibility and genetic variability of the bacterial isolates can be influenced by the management system. Recent studies have also shown that reducing antimicrobial use in intensive pig production is feasible without jeopardizing animal health and production (Postma et al., 2017).

Environmental Contaminants

The risk for the intake of environmental contaminants, e.g., toxic metals, is almost negligible in pigs that are housed in confinement. However, when animals are raised outdoors, exposure to environmental contaminants through soil ingestion by foraging can occur. Information on toxic metal exposure through the soil in pigs is not available in the literature, but results in beef cattle indicate that toxic metal accumulation in animal tissues is directly related to grazing activity, which is a reflection of soil ingestion when grazing (López-Alonso et al., 2012). Because of the great rooting activity of pigs, soil ingestion can be very high (Rivera-Ferre et al., 2001) compared with ruminants and the effect of (possibly contaminated) soil ingestion on residues of toxic substances in tissues should not be neglected. In intensive large-scale systems with least cost rations, incidents with feed contaminants (e.g., dioxins) may affect a large number of animals and farms in a very short period of time (Bernard et al., 2002).

Animal Welfare

Animal welfare is multidimensional and can be measured in many different ways. The Welfare Quality assessment method, further developing the Five Freedoms from the UK Farm Animal Welfare Council (1992), uses 12 independent welfare criteria (Welfare Quality®, 2009). They can be grouped into four main principles: good feeding, good housing, good health, and appropriate behavior (Table 2). The Welfare Quality assessment predominantly utilizes animal-based measures, e.g., health and behavior outcomes measured on the animals themselves, rather than resource-based measures describing the environment in which they are kept.

Good Feeding

The absence of prolonged hunger and thirst should be ensured by providing pig category-specific diets and fresh water. In intensive systems, complete concentrated feed is provided according to the needs of the animals (age, body condition, and reproductive cycle). Some groups, e.g., pregnant sows, might be fed restrictively. There are limited opportunities to express foraging behavior and animals occupy much less time with eating than in natural conditions, which can give rise to abnormal oral stereotyped behaviors and increased aggression (Edwards, 2018).

In extensive systems, the feed quality and quantity can be more variable. In outdoor environments, malnutrition of pigs is common, especially in sows (Lucović et al., 2017). Because of group feeding of all categories, sows kept extensively are mostly not fed individually according to body condition, and competition, aggression and inequality of intake at feeding may, therefore, be a serious problem.

Drinking water is mostly supplied ad libitum. In situations where natural sources of drinking water are used, water quality

Table 2. General evaluation of animal welfare parameters in intensive pig production systems

	Critical	Comments
Feeding	Complete concentrated feed: less foraging behavior, less time to eat	Diet provided according to needs
	Restricted feeding: hunger, less time to eat	Individual feeding possible and balanced body condition
	Drinking water	Provided ad libitum and good quality
Housing	Floor: often slatted, concrete, barren	Lameness critical in case of group housing
	Risk for lameness, claw and skin lesions	
	Air quality: stable gases and air pollutants	Controlled environment
		No sunburn or freezing problems
	Temperature fluctuations	Mostly proper ventilation
Health	Tail docking: applied on many farms, painful	Limits or prevents tail biting
	Teeth clipping: applied on many farms, painful and/or causing stress	Limits or prevents skin lesions or restlessness of the sow during suckling
	Nose ringing: not done	
	Individual monitoring	Easier, assistance by technology
Behavior	Environmental stimulation: low	Enrichment
	Freedom to move: low	More space, lower stocking densities
	Group formation and social organization: no or limited influence	
	Escape possibility: low or absent	Possible in some housing designs, no risk for predators
	Nest building behavior: very low or absent	Enrichment, loose housing farrowing/lactation
	Feed intake behavior: altered, no influence	Fiber-rich diets, bulky feed, and ad libitum feeding
	Rooting, wallowing behavior: altered, not possible	Enrichment
	Moving and mixing: done on several occasions on most farms	Homogeneous groups according to weight and gender
	Aggression, tail biting, and stereotypic behavior	Enrichment and proper stable climate
	Stress levels: might be increased	Enrichment

cannot always be assured and there might be a problem of freezing during winter or extreme droughts in the summer (Lucović et al., 2017. Poor water quality is a frequently observed problem in pig production (Filipitzi et al., 2018).

Good Housing

This implies comfort around resting, thermal comfort, and ease of movement. Critical areas for pigs in intensive systems relate to space allowance, type and quality of the floor, and temperature control inside buildings where animals have no possibility to select their own environment (EFSA, 2005, 2007). Inappropriate slatted floors can cause skin lesions and lameness at all production stages, while poor design or management of heating and ventilation can result in heat stress in finishing pigs during hot summer weather and too cold an environment for neonatal piglets, predisposing to disease and mortality.

Outdoor pigs have more choice of location and can use natural thermoregulatory behaviors such as wallowing in mud, mainly for cooling, sunburn protection, and the removal of ectoparasites (Bracke and Spoolder, 2011). However, they are also exposed to extremes of weather and need effective shelters for protection against the sun during summer and against cold and damp in wintertime (Edwards, 2005).

Good Health

This implies the absence of injuries, diseases, and the absence of pain induced by management procedures. The first two items have been discussed already. Teeth clipping and tail docking of piglets are commonly practiced to prevent udder and facial damage during suckling competition, and to reduce the risk of tail biting in later life, although in the EU, these procedures are not allowed to be carried out routinely (Directive 2008/120/EC). In outdoor pigs, procedures like tail docking and teeth clipping may sometimes not be used at all, although this often depends on the level of risk associated with the subsequent housing of the pigs after weaning. Nose ringing of sows is widely practiced in outdoor pigs, mainly to reduce the pasture damage that is caused by rooting of the paddock and the associated welfare and environmental impact of bare muddy fields (Edge et al., 2005).

Appropriate Behavior

This relates to the expression of social behaviors, other behaviors, good human–animal relationship, and positive emotional state. Intensive systems offer low levels of environmental stimulation for the pigs and limit their available choices, freedom of movement, and activities. The confinement conditions interfere with group formation and social organization; decrease the possibility to escape from aggression; change the pattern of social contacts and mother–offspring interactions; change feed intake and eating behavior; and limit or make impossible some natural behaviors, e.g., rooting, wallowing, exploring, and nest building (Svendsen and Svendsen, 1997).

To satisfy intrinsically motivated exploratory and (possibly) foraging behavior, pigs need manipulable materials, such as straw (Van de Weerd and Day, 2009). When these materials are absent or inadequate and exploratory motivation is frustrated, play behavior reduces and there is manipulation of other pigs resulting in fighting and skin lesions, in particular tail biting. Tail biting is a major health and welfare problem because of the pain experienced by the bitten animal, the stress caused to the group and the likely frustration of the biting animal (Taylor et al., 2010). The injury can also lead to associated infections.

Under natural conditions, pigs typically live in family groups of about 8 to 10 adult sows, some young individuals, and in the periphery, some single males (Edwards, 2018). The lack of space and the artificial group structure of pigs in intensive farms negatively influence social interactions. Social behavior related to grouping or mixing of pigs in different production stages is also often disturbed, resulting in aggression among animals (Peden et al., 2018).

The space restrictions are most pronounced for sows housed in crates. In the EU, pregnant sows from 1 mo of gestation until 1 wk prior to expected farrowing must be housed in groups, and nesting material before parturition must be provided unless precluded by manure management constraints (Directive 2008/120/EC). Most sows in the farrowing house are still housed in crates. Farrowing crates were developed to help reduce piglet losses because of reduced crushing by the sow, a better thermal environment with localized heating, safer working conditions for stockperson interventions and improved hygiene through the use of perforated floors. In this way, piglet mortality was reduced by half (Baxter, 1989). Different nonconfinement pen systems for farrowing and lactation indoors have been developed (Baxter et al., 2011), although most of them have led to higher piglet mortality (Baxter et al., 2012), which is a clear piglet welfare issue. While some more recent systems show greater success, this is highly dependent on good management, experienced stockpersons, and the selection of appropriate sow genotypes (Baxter et al., 2017).

In intensive production systems, pigs have much closer contact with humans for routine handling tasks, especially in the case of the breeding sows. The quality of such contact can have a major influence on the chronic level of fearfulness felt by the animals. Good staff recruitment and training are therefore of great importance for their welfare (Hemsworth and Coleman, 2011). In contrast, pigs in extensive systems may receive less human contact, which might make any necessary handling, such as at the time of veterinary treatment, transport, and slaughter, much more stressful for them.

Control Measures To Improve Health And Welfare

Different measures can be implemented to prevent or control the different critical issues related to health and welfare in intensive systems. Some of these measures are not specific to intensive systems only and might also be applicable for extensive systems.

Management and Biosecurity

Pathogen eradication is the most effective form of prevention. If the pathogen is not present, then health and welfare problems caused by the pathogen are not possible. Therefore, herds that obtain a specific-pathogen-free (**SPF**) status (https://www.spf.dk/en-us/health/the-danish-spf-system) generally have a higher animal health and welfare status, and less antibiotic use than non-SPF herds.

Biosecurity is the application of management practices that reduce the opportunities for infectious agents to gain access to, or spread within, an animal production unit (Toma et al., 1999; Maes et al., 2018). External biosecurity comprises measures that prevent pathogens from entering the herd, while internal biosecurity relates to preventing the within-herd spread of pathogens. Different studies have quantified biosecurity in commercial pig herds (Laanen et al., 2013; Postma et al., 2016; Chantziaras et al., 2018; Rodrigues da Costa et al., 2019), with 100% being the perfect biosecurity situation and 0% the total absence of any biosecurity measures (www.biocheck.ugent.be). Average scores in these surveys ranged between 50% and 80%, but in general, there was a lot of variation between farms, meaning that there is potential for farms to improve biosecurity (Filipitzi et al., 2018).

External biosecurity scores were positively associated with herd size, while internal scores were negatively associated with both "age of buildings" and "years of experience of the farmer," indicating that biosecurity is generally better implemented in larger herds, in more modern facilities and by younger farmers. Internal scores were negatively associated with disease treatment incidence, suggesting that improved biosecurity might help in reducing the prophylactic use of antimicrobials. Pandolfi et al. (2018) indicated that internal biosecurity in UK farms was generally lower than external biosecurity, and more strongly connected to the general level of biosecurity. While the biosecurity can be improved by taking further measures or adopting new habits, they also elucidated possible limitations in farm infrastructure and a smaller impact of biosecurity regarding issues such as mortality, prevalence of lameness, and pigs requiring hospitalization.

In general terms, biosecurity measures can be more easily implemented in intensive systems than in extensive systems. In extensive systems, particularly in case of outdoor housing, it is more difficult to avoid contacts with external and possibly contaminated sources. Also, factors related to cleaning and disinfection are more difficult to implement in extensive systems. While fencing can be used to limit or avoid contact with wild pigs, contact with pathogen-carrying birds cannot be prevented. Parasitic control in extensive systems can be based on the principles used in ruminants, namely turn-out on safe pastures, pasture rotation, mixed or alternate grazing with other animal species, and integrated use of anthelmintics (Roepstorff and Nansen, 1994).

Vaccination

Improving the immunity status of susceptible animals, e.g., by vaccination, is a helpful tool to control infectious diseases. Commercial vaccines against important pathogens are commonly used in sows and piglets on commercial farms. Vaccination is generally able to reduce the (risk of) clinical symptoms, lesions, and performance losses due to disease. However, most vaccines only provide partial protection, do not prevent infection, and are not able to eliminate the pathogens from the herd. Also, commercial vaccines are only available against specific diseases, not against all pathogenic infections.

Nutrition

Nutrition is a key factor for pig health and welfare. Feeding pigs according to minimal nutritional requirements can prevent deficiencies or disease, but may not be sufficient for optimal (intestinal and behavioral) health and welfare. The feed composition and the physical characteristics of the feed, the feeding level as well as the way of feeding and feeder space per pig are all important. The severity of endemic diseases such as infections with *E. coli* postweaning, *Brachyspira* spp. and *Salmonella* are largely influenced by nutritional aspects. Feed additives such as organic acids and enzymes, pre- and probiotics may be beneficial to improve intestinal health (Barba-Vidal et al., 2019), and may serve as alternatives to antimicrobial use (Vanrolleghem et al., 2019).

Sows should be provided with sufficient quantities of high-fiber and high-energy food (EC Directive, 1991). Fermentable fibers in the diet provide satiety to the animals and reduce stress. An ideal feeding system should permit the feeding of sows in groups so that each animal receives her ration at the same time as the others and is permitted to eat undisturbed. Besides the positive effect on sows, Bernardino et al. (2016) noted that high-fiber diets during pregnancy are associated with less aggression among piglets prior to weaning. It was suggested that high-fiber diets lead to less hunger in the sows in the prenatal and neonatal environment, with positive effects on the behavior of the piglets born from these sows in the preweaning period.

Genetics

Many health and welfare problems have a heritable component, meaning that genetic selection should be considered as a potential tool for improvement. The genetic selection for high production needs to be re-evaluated, with more emphasis on sow longevity, piglet survival, and welfare traits. In highly prolific sows, the number of live-born piglets is often larger than the number of functional teats. The management interventions and the many manipulations that are practiced when litter size exceeds the ability of individual sows to successfully rear all the piglets, could serve as additional triggers of stress, and reduced welfare for sow and piglets (Rutherford et al., 2013).

Different breeds adapt differently to environmental changes, handling conditions, and other stressors (Mkwanazi et al., 2019). Therefore, new genotypes could be developed that are better suited for either intensive or extensive conditions, allied to enhanced welfare.

Other options are to breed for disease tolerance or resistance (Nakov et al., 2019). Disease tolerance is the adaptive ability in preserving homeostasis and at the same time limiting the detrimental impact that infection can inflict on health and performance, without affecting the pathogen burden *per se* (Doeschl-Wilson and Kyriazakis, 2012). Disease resistance is the ability to actively diminish the pathogen burden or prevalence through the inhibition of the infection and through the reduction of bacteria/viruses growth rate. In pigs, Whitworth et al. (2015) edited the gene that makes the CD163 protein, which is important during infection with PRRS virus. Treated pigs no longer produced the protein and were protected against clinical disease upon experimental PRRS challenge infection. The development of genetic resistance against diseases in pigs has however been slow and uneven so far. It has been a long and ultimately unsuccessful battle to develop useful *E. coli* resistant piglets.

Environmental Enrichment and Appropriate Housing

Environmental enrichment is the modification of a barren captive-environment to improve the biological functioning of animals (van de Weerd and Day, 2009). Enriched environments enhance the well-being of animals by allowing them to perform more of their species-specific behavioral repertoire and accommodate a larger range of behavioral choices. They prevent or limit aggressive or stereotypic behavior. Commonly used enrichment objects are straw bedding, suspended ropes and wood shavings, toys, colored plastic keys, table tennis balls, chains, and strings. To be most effective, substrates need to be chewable, deformable, destructible, and ingestible (Mkwanazi et al., 2019). Herskin et al. (2016) showed that permanent access to straw reduced gastric ulceration in fattening pigs raised in conventional conditions, indicating that sufficient straw may improve animal health.

Floor characteristics, such as slat and gap width, slipperiness, wetness, dirtiness, and quality of available bedding material, are of paramount importance to avoid lameness and claw lesions, in particular in the case of pigs that are permanently housed indoors (Pluym et al., 2013).

Environmental inadequacy has been repeatedly identified as a major cause of injurious behaviors such as tail biting. However, Danish studies (Alban et al., 2015; Kongsted and Sörensen, 2017) showed that extra-space allowance, access to outdoor areas, and the provision of straw were insufficient to prevent tail biting in pigs with entire tails. In both studies, pigs from the welfare label systems with undocked tails had approximately three times higher odds for tail lesions compared with conventionally raised pigs with docked tails.

Discussion remains as to whether basic enrichment is sufficient, e.g., when sows are housed in crates, or whether more drastic changes in the housing should be implemented by providing environments that are conducive to positive emotional states (Reimert et al., 2013). Further research is required on how to promote such states via practical and economic methods on intensive farms. Moreover, animals differ in their genetics, early experiences, and temperament, and therefore, they may experience the same environment in different ways.

Welfare legislation in the EU has evolved significantly toward more animal-friendly conditions, and further adaptations can be expected in the future. However, legislation varies among continents and countries. It is positive to see that many pig farmers already implement extra animal welfare measures on top of what is minimally required by legislation, and that such developments can be audited and/or rewarded through farm assurance schemes with product labels (Hubbard, 2012). Further research is warranted to investigate loose housing systems for lactating sows that can accommodate the behavior needs of the sows without jeopardizing the health and welfare of the piglets.

Reducing Painful Interventions

In EU legislation, tail docking and teeth clipping should not be practiced routinely, but only temporarily when problems associated with them cannot be solved by other prevention measures. While measures to reduce tail docking are the subject of intense political focus in the EU, the problem of tail biting remains intractable in current farming systems, making this a major welfare challenge (De Briyne et al., 2018).

Surgical castration of male pigs is painful and therefore animal-friendly alternatives to avoid boar taint should be developed and implemented in pig farms. In more and more farms, animal-friendly alternatives, e.g., vaccination against boar taint and raising entire males, are used. However, it does not seem likely that surgical castration will be phased out in the short term (De Briyne et al., 2016).

Alternatives to the use of nose rings in outdoor pigs have been suggested, but the only effective way to reduce pasture damage due to rooting is to assure enough large area and to rotate pastures (Edge et al., 2005).

While they remain necessary, all procedures and interventions should be applied by properly trained persons to reduce stress as much as possible.

Increasing the Monitoring of Individual Animals

For any pig production system, adequate levels of on-farm monitoring are necessary. This refers to the frequency and duration of the checks, as well as to the level of attention given to individual animals. Daily monitoring of animals, identifying and isolating pigs that require treatment is easier in conventional indoor pens than in outdoor systems or in large groups, but as farm size increases and staffing levels reduce, it becomes more challenging.

Information and communication technologies are reaching swine production including almost ubiquitous wireless connection (3G/4G, Wi-Fi, and satellite), powerful mobile devices (cell phones and tablets), sensors, and cloud computing. It is possible that in the future, individual identification of pigs through electronic tags will be routine in pig systems. Moreover, producers are becoming aware that their competitiveness depends largely on using data properly to support their decision-making process.

Animal-oriented data can be collected either by humans, the most important source until now, or automatically, e.g., from electronic feeding or weighing systems, but other methods are appearing quite fast in the market. These are, e.g., images that can be processed and analyzed for different purposes, including disease detection, behavior, or weight calculation.

Environment-oriented data are mostly collected from sensors and farm equipment and are key to control and minimize environmental stress produced by variations in temperature, humidity or gasses, that have been widely described in pigs as triggering or worsening health problems, including respiratory diseases in confined barns (Maes et al., 2018).

In this respect, the PROHEALTH project showed how big data can be used to fight diseases. A neural network was trained on raw sensor data to identify factors that lead, or not, to an increase in respiratory disease prevalence in pigs (Cowton et al., 2018). This system out-performed state-of-the-art disease alert techniques and showed that a change in the pigs living environment, measured by sensors, can detect an increased number of pigs showing symptoms 1 to 7 d in the future.

The use of both animal- and environment-oriented data supports easier and proper monitoring of health, welfare, production, and risks (Berckmans, 2019, Piñeiro et al., 2019). However, oversight and interpretation of the data by skilled persons remain essential.

Stockmanship

Since intensively housed animals are fully reliant on the stockperson to meet their needs, management is of utmost importance (Coleman and Hemsworth, 2014). In reality, any pig raising system is only as good as the expertise and experience of the stockperson working in the system. Pigs can get sick in all systems; pigs can get stressed in all systems.

The relationship between the pig and stockperson in terms of pleasant contact, stimulation and the creation of a stable and caring environment is, therefore, very important. Stockpersons should not become too much habituated to animal health and welfare problems and therefore fail to recognize and solve them. In high-income countries, attracting skilled personnel for a career in the pig industry is a major challenge. It is possible that to a certain extent, this will be accounted for by an increase in automation in intensive pig systems. The challenge would be to balance reliance on automation and the benefits from good stockmanship.

Integrated Health and Welfare Plans

Given the multifactorial nature of most problems, sustainable solutions often involve various disciplines and therefore call for a multidisciplinary and integrated approach. Preventive measures and routine examinations are the core of health programs, but deeper involvement of nutrition, production, and economics may be warranted.

Further Considerations

Improving the Transparency of Pig Farms to Promote Public Involvement

The justification for intensive pig production will likely remain an issue of public debate in high-income countries. An increasing number of people live in urbanized areas and are not familiar with farming practices. Their lack of knowledge, along with the increased media attention for the critical issues of intensive production (animal welfare, antimicrobial resistance, and environmental impact), may lead to excessive and unreasonable criticism toward pig farmers and pig health professionals for social irresponsibility and gambling with welfare, public health, and the environment. In specific situations, this might even result in the stigmatization of these persons (Fynbo and Jensen, 2018). Therefore, informing the public properly about the health and welfare of the animals, and providing greater transparency in farming operations, eventually by providing (digital) visual access to the animal facilities, might be required.

The competency of stockpersons and farm conditions might be evaluated by independent assessors in order to maintain the right to raise animals for food production, or to achieve market differentiation. This is already the case for pig farms that produce according to specific label conditions (Edwards, 2008).

Differentiation of Production Characteristics

Grunert et al. (2018) suggested that production characteristics can be used to position pork products. They found that production characteristics do not appeal to all consumers in the same way, and therefore, segmentation might be interesting, i.e., different bundles of production characteristics apply to different consumers. Although some participants of the study considered animal-welfare-related production characteristics as important, the most attractive production characteristics centered around health and safety. This implies that the market might benefit from specific positioning based on production characteristics related to health and safety, like low use of antibiotics, guaranteed absence of microbial contamination, and guaranteed GMO-free feed.

Conclusions

Most pigs in high-income countries are raised indoors in intensive systems. Although these systems often raise concerns by the public, they allow animals to grow according to genetic potential and offer many advantages in terms of animal health, food safety, hygiene and biosecurity, and some welfare advantages when compared with extensive conditions. However, critical issues for pig health, and especially welfare, in intensive systems remain. Comparative studies with extensive production systems are scarce and often difficult to interpret. Animal behavioral opportunities are clearly improved in extensive systems, but this must be weighed against other issues such as specific diseases and lesions, pork safety, uneven body condition, and lower efficiency.

Measures to optimize health mainly relate to management and biosecurity, vaccination, and nutrition. This is consistent with consumers' views, who favor improved housing and hygiene measures as ways of improving pig health and welfare (Clark et al., 2019). Improvement of animal welfare can be accomplished by focusing on environmental enrichment, proper housing conditions, providing more space for the animals, genetic selection with emphasis on piglet viability and survival, disease tolerance and resistance, and the development of genotypes that match better with different raising conditions, reducing or banning painful interventions, and better monitoring of the animals, eventually in combination with digital technology. Skilled stockmanship remains the key to success.

Overall, intensive pig production systems perform well in terms of animal health, pork safety, and some welfare parameters. High antibiotic use, limited space, and restricted behavior for the animals (e.g., housing in crates) are the most critical factors to solve.

Public debate is likely to persist as to whether intensive pig production should continue with ongoing improvement by implementing "rather minor modifications" to the current systems, or whether more drastic changes toward extensive systems, allowing animals to express much more natural behavior, are warranted. This discussion, and/or whether it is ethically justified to continue intensive livestock production or even use animals as such for food production, is especially important for those who live in high-income countries, representing ~20% of the total world population.

Apart from the above considerations, other factors such as efficient use of resources, land and production, environmental impact and, *last-but-not-least*, food security will determine the future of the systems. Given the predictions of a growing world population, the demand for animal protein will increase, even if meat consumption *per capita* decreases in the high-income countries. Therefore, and also because of the problem of limited natural resources and environmental impact, efficient and also sustainable systems will be required. In this respect, intensive pig production will likely remain and even grow. Other food production systems such as artificial meat produced from stem cells will likely develop in the future and, if they appear to meet most sustainability criteria, they might decrease the pressure to further expand intensive animal production.

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Conflict of Interest Statement

None declared.

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