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Review

Animal Welfare and Production Challenges Associated with Pasture Pig Systems: A Review

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Abstract: A review of published literature was conducted to identify pasture pig production system features that pose risks to animal welfare, and to develop recommendations aimed at improving the wellbeing of the animals managed in those systems. Pasture pig production systems present specific challenges to animal welfare that are inherent to the nature of these systems where producers have little room to make improvements. However, these systems present other challenges that could be reduced with a carefully designed system, by adopting appropriate management strategies and by avoiding management practices that are likely to negatively affect animal wellbeing. In pasture pig production systems, exposure to extreme temperatures, potential contact with wildlife and pathogens (especially parasites), vulnerability to predators, risk of malnutrition, pre-weaning piglet mortality, complexity of processes for monitoring and treating sick animals, and for cleaning and disinfection of facilities and equipment are among the main threats to animal welfare.

Keywords: pasture pig systems; threats; animal welfare; pasture-based pig systems; pig production; alternative pig production

1. Introduction

The new millennium brought a worldwide growing interest for animal welfare [1]. The livestock sector reacted by developing recommendations relevant to the wellbeing of farm animals, consequently encouraging producers to adopt and implement them. Additionally, consumer demand for better production practices contributed to the development of responsible production systems in which animal welfare principles are incorporated into daily management practices. These systems are generating animal products that represent an alternative to satisfy niche-markets customers who require ethically sourced, safe, healthy, and environmentally friendly-produced goods. For this reason, one can infer that animal welfare presents ethical and productive implications. However, the multidimensional character of the welfare concept complicates reaching a consensus around a unique definition [2].

The different components of the pork supply chain can have divergent perceptions regarding animal welfare. Consumers emphasize the mental aspect of animal welfare, relating it to the prospect of providing animals with living conditions that resemble natural settings [3]. Veterinarians, scientists, and other animal care professionals' orientation toward animal welfare pay more attention to the physical health, animal performance, and production efficiency [4]. Farmers, being conscious of the animal welfare impact on productivity, focus on the physical wellness of animals prioritizing performance and health. Farmers' actions to improve animal welfare have been associated in increases in productivity [5]. Millet et al. suggest that the different pork supply chain stakeholders' points of views do not align; moreover, it would seem that they are not founded on similar scientific grounds [6]. Additionally, different welfare problems could be weighted differently by the different interested parties [6,7].

The combination of these different perspectives in welfare have evolved into a more complex and holistic concept, which should be assessed by trained personnel. It is worth noting that animal welfare is a broad and complex [6] concept that involves aspects related to physiology, physical health, emotional state, and animal behavior. The World Organization for Animal Health (OIE) defines animal welfare as the state of the animal that reflects the way it is coping with the conditions in which it lives [8]. To attain satisfactory animal welfare, animals need to be provided with responsible care, proper housing, prevention and treatment of diseases, adequate management and nutrition, humane handling, and when needed, humane euthanasia. Overall, animals should be kept in a distress free environment where they are free to express their innate behavior [9].

Pork is the second most consumed meat in the world [10] and it can be produced within a variety of production systems, ranging from extensive backyard to highly specialized indoor systems. The level of welfare that animals may experience within each of the production systems is also diverse. Public perception tends to relate extensive systems with lower environmental impact and better animal welfare [11,12]. Groups of consumers declared a willingness to pay preferential prices for products derived from these kind of production systems [13,14]. In 2019 the National Restaurant Association showed that since 2014, sustainably raised, and locally produced beef and pork cuts appear in the top ten overall choices of their customers [15]. Furthermore, studies conducted in the United States showed that 78% of consumers rated as "important" the way food animals had been raised [16]. This evidence supports the existence of a favorable purchasing behavior toward pasture-raised meat. Previous studies associated animal welfare mostly with management practices and how well those operated instead of focusing on production system typology [17–19].

Among the extensive systems, it is important to mention pasture-based pig production systems in which pigs of different productive categories are kept on pastures where they can graze, receive feed and water, and are provided with shelter [20]. In addition to their contribution to animal nutrition, the presence of well-established pastures reduces the creation of mudflats, soil compaction, and runoff [21]. The lack of ground cover has been associated with greater piglet mortality rates attributed to mud being brought inside the huts by the sows, boosting humidity and bacterial contamination [22]. The implementation of pasture rotation and adequate animal stocking rate adapted to edafo-climatic conditions, forage species, and grazing animal categories, favor the maintenance of plant cover [21]. Pasture environments approximate the natural habitat of pigs, which is conducive to the expression of foraging, rooting, and exploratory behaviors. Pastures contribute to animal comfort while modifying the temperature near the soil surface leading to enhanced animal welfare [20,23,24]. Greater environmental complexity, the opportunity of selecting both the physical and social environment, and the greater availability of space per animal are advantages attributed to pasture pig systems when compared to indoor confinement systems [17]. However, if not properly managed, these systems may pose risks both to the environment [21] and to animal welfare [25,26], especially for subordinate individuals [17].

Animal welfare assessment comprises measurements of physiological responses, health, behavior, and productivity. Animal welfare has been broadly studied for pig units, leading to the definition of science-based best management practices available to farmers for improving the functioning of their operations. However, despite the enormous amount of information, few studies have focused on animal welfare in pasture-based pig operations. This document aims to review scientific information on pasture pig production systems, identifying system features that pose risks to animal welfare, and suggest recommendations to improve the wellbeing of the animals managed within such systems.

2. Materials and Methods

A search in the literature was conducted to identify potential threats to animal welfare that are likely to impact pasture pig production. The search conducted in the database Web of Science included 20 years of data from 2000 to 2020, and was performed exploring the keywords: pasture pork, pasture pigs, free-range pig systems, pasture-based pigs, outdoor pigs, organic pigs, animal welfare, and pasture pig production. The review was limited to on-farm processes. Transport and slaughter impact on pig welfare were considered beyond the purposes of this paper.

The initial search yielded 250 articles, which were subsequently screened based on reviews of the abstracts. Unrelated articles were excluded. This filtering yielded 187 articles. Complementary searches related to specific topics included in the manuscript outline that appeared lacking in information were performed using Google and Google Scholar. A total of 238 articles fulfilled the inclusion criteria and were incorporated in the review. Scarcity of information specific to pasture pig systems, which was one of the main constraints found, was overcome by including information related to outdoor, free-range, and organic pig production systems.

3. Results

3.1. The Pasture Environment

Pastures are complex ecosystems where a great variety of elements and organisms interact. They are similar to the environments in which pigs evolved, and consequently better suited to fulfil their physiological and psychological needs than other systems [24,27]. Pasture and indoor-confinement rearing environments differ considerably and might generate differences in the welfare of pigs managed in those production systems. A note of caution was raised by Pandolfi et al. when reviewing the results of welfare studies in pasture production systems with pigs resettled from other systems. The previous rearing environment, management, pig health, wetness, filthiness conditions of pens and paddocks, and stocking rates can lead to unexpected responses to the pasture systems [28].

Location of the pig unit can represent a challenge to pig welfare. The health and welfare of sows reared on pastures will be reliant on ground conditions, which is related to soil texture, proneness to flooding, stocking rate, and stocking management [29,30]. Greater prevalence of health issues and mortality rates are expected in poached soils because these conditions favor pathogens and parasite survival as well as pigs remaining wet and dirty [23]. Additionally, muddy soil can become slippery and can cause falls and injuries [31]. Similarly, stony soils could cause feet injuries, joint ailments, and ultimately lameness. Soft soil could cause overgrown claws while damp soil conditions could cause toe erosion in older pigs [32]. Holes, hollows, tree stumps, wires, or thorns can be the cause of injuries and lesions [33]. Sites exposed to strong winds, and where long periods of extreme cold, frost, and snow can be expected, are also not appropriate. Careful choice of location, suitable housing, and implementing of adequate management strategies can alleviate the negative impacts of the environment on pig welfare.

3.1.1. Exposure to Climatic Elements

Weather conditions including precipitation, temperature, humidity, solar radiation, wind strength, wind direction, rainfall, and atmospheric pressure can cause stress to pigs kept on pastures [25,34]. The initial manifestations of stress to weather are restlessness, irritation, and aggressiveness [35], followed by other behavior changes. Ultimately, extreme weather leads to injuries, lower growth rate, and reproductive performance (boar libido, semen quality, and reproduction rate), and in the manifestation of stereotypes [36]. The impact of environmental conditions on pigs will vary depending on age, weight, reproductive stage, health condition, feeding status, and production systems [29,35]. Heat or excessive cold could cause thermal stress on grazing pigs [12,25,37]. The upper limit of the temperature comfort zone decreases as pigs age, 32 to 35 °C for pigs under 3 kg, 26 to 35 °C for pigs in pre-nursery, and 10 to 35 °C for grower-finishers and sows and boars greater than 100 kg [38]. Lactating sows could suffer more from heat stress as a consequence of their higher feed intake and metabolic activity, whereas dry sows can be more prone to cold stress because of their feed restriction level [30]. The preferred temperature for dry and lactating sows oscillates between 12 to 31 °C, and 7 to 26 °C, respectively [39,40].

In a study where average temperature varied between 15.6 and 29.0 °C, and temperature humidity index (THI) fluctuated between 62.4 to 75.1; it was shown that increased temperature at the moment of service favors sow reproductive performance with a greater number of piglets born, whereas when high temperatures take place at farrowing the reproductive performance of sows is negatively impacted [12]. Impaired reproduction derived from heat stress has been related with embryonic losses in sows, and decreased spermatogenesis and lower libido in boars [33]. Sows exposed to high temperature (≥22 °C) have shown longer farrowing and longer birth intervals among piglets. Conversely, piglets profit from greater temperature and temperature–humidity indexes after farrowing, with a significant decrease in pre-weaning mortality [12]. Furthermore, season and environmental temperature have shown to influence piglet mortality [41]. For instance, increased numbers of stillborn have been reported during periods of high temperature (≥27 °C) [42]. Similarly, sows exposed to temperatures greater than optimum showed reduced feed intake and milk and colostrum production, shorter nursing periods, and increased piglet mortality, as a direct result of crushing and starvation [23,33,43,44].

Even though in grazing systems animals are exposed to weather conditions to which they would not be exposed to in confinement, they have greater opportunities to express thermo-regulation behaviors including wallowing, changing position, and modifying their lying posture (huddling, piling, and spreading out) [45]. Sows kept on pastures showed lower heat stress, with respectively lower skin temperature (32.1 vs. 30.8 °C) and lower respiratory frequency (31.04 vs. 26.07 mov/min) than sows managed indoors [46]. The impossibility of pigs to relieve themselves from high temperatures can lead to displays of stress and become a welfare issue. The European Food Safety Authority (EFSA) has reported an increase in tail-biting episodes frequency among pigs due to high temperature. Heat stress begins to manifest itself with panting but if not controlled it could lead to collapse and death of the animal [47].

In East Balkan traditional breeds seasonal differences in activity and behaviors were identified for piglets. Piglets were more active during spring-time and cooler times of the days as compared to summer and warmer times of the day. During cooler temperatures piglets were more active and fed more intensively, whereas during warmer temperatures resting in the shade and wallowing were more frequent [48]. These authors concluded that environmental temperature and reduction in vegetative ground cover are important factors that impact behavior and productivity of pasture pigs [48]. Parrini et al. reported a similar behavior towards heat stress in Cinta Senese, an Italian heritage breed, and their crosses with Large White [34]. Similarly, seasonal influence has also been reported in piglet mortality, where higher mortality rates were found during the summer and lower in the spring [37,48].

Low temperatures could cause hypothermia in pre-weaning and recently weaned piglets in pasture systems; thus, becoming a potential risk for their welfare [29,49,50]. Pigs managed under low temperatures grow slower and are more susceptible to diseases such as pneumonia caused by *Mycoplasma hyopneumoniae* [51]. Adult pigs tolerate low temperatures better than higher ones. However, when subjected to long periods of low temperatures, older pigs can lose body condition [29]. Indoor-managed animals maintained constant rectal temperatures throughout the seasons, whereas outdoor pigs' rectal temperatures fluctuated throughout the seasons, which could translate into difficulty managing temperature during winter months. Outdoor-housed sows showed a greater variation in back-fat, longer claws, and lower reproductive rates [29]. Wind and snow intensify the effects of low temperatures. Snow accumulation can also restrict access to areas where animals are located or affect electric fencing. The impact of the wind on animal welfare differs among seasons.

In the course of hot weather, wind can be favorable contributing to heat dissipation, but the opposite can happen during cold weather when it would be necessary implement measures to minimize its effect. Wind can influence the location of the pigs in the paddocks. Regardless of environmental temperature, pigs will avoid exposure to areas of high wind speed and their response to it will depend on seasons, breeds, and body weight [35,51]. Pigs that did not have access to wind protection during winter showed decreased growth rates. Duroc pigs showed greater improvements in growth rates compared to Yorkshire or Danish Landrace pigs. Heavier pigs (weight ≥29 kg) performed better in unshielded pens [51].

Contrary to many indoor-confined pigs, pasture pigs are exposed to sunlight. Exposure to natural photoperiod could impact the reproductive behavior and performance of sows [39]. Decreases in milk production have been related with shorter photoperiods [23]. High solar radiation can cause sunburns in animals with light colored skin, which can show redness of the skin and changes of posture caused by pain [26,29,52]. Additionally, photosensitization in response to the ingestion or contact to certain plants such as parsley (*Petroselinum crispum*) [53], turnips, parsnips, rape (*Brassica* spp.) or celery (*Apium graveolens*) leaves [33], (*Medicago sativa*), clover (*Trifolium* spp), oats (*Avena sativa*), carrots (*Daucus carota* subsp. *Sativus*), and buckwheat (*Fagopyrum esculentum*) [54] can also cause severe blistering to sun exposure. Pigs grazing bermudagrass (*Cynodon dactylon*) have presented signs of photosensitization and ataxia (author's personal observation, unpublished), which are consistent with the symptoms (incoordination of the forelimbs, collapse of posterior legs, stiffness, and crab crawling) described by Williamson et al. [55]. These animals recovered quickly when placed in the shade.

Some weather elements can also have a combined effect on pigs' behavior. Pigs used shelters more frequently with high environmental humidity, wind, and low temperature. Sow nesting behavior is also influenced by environmental conditions. The effort of sows, the location of the nest, and the amount of materials used in cold, rainy, and windy conditions seem to prompt the construction of stronger nests that can provide more protection to the piglets than nests built under high environmental temperatures [35]. Cold and drafty conditions could lead to an increase tail biting resulting in higher rates of tail lesions among outdoor-managed pigs as compared to indoor-reared pigs. Furthermore, outdoor pigs could also have higher prevalence of skin lesions during summer and attributed them to insect bites compared to indoor pigs [11]. Additionally, African swine fever also presents a seasonal prevalence in free-range pigs in Sardinia, Italy [56].

3.1.2. Exposure to Wild Animals and Pathogens

Exposure to Wild Animals

Pasture pigs could be exposed to biosecurity threats to a greater extent than pigs reared in confinement [12,57]. The health and well-being of grazing pigs may be threatened by exposure to wild animals which can act as predators or be pathogen reservoirs [58–61], transmit diseases [62], damage equipment and facilities, and ingest and contaminate both feed [63] and bedding of grazing pigs [58,63,64]. Some of these threats include: insects, snakes, birds, rodents, raccoons (*Procyon lotor*), badgers (*Meles meles)*, foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), feral pigs (*Sus scrofa domesticus*), wild boars (*Sus scrofa L.*), ravens (*Corvus corax*), eagles (*Aquila audax*), and feral and pet dogs (*Canis lupus*), and cats (*Felis catus*) [23,58–60,65,66]. The lack of appropriate fencing and the closeness to wooded areas encourage predator attacks [23]. Predators prefer to prey on piglets but scare adult pigs to the point that they break fences and escape. In lactation paddocks, this could cause piglet mortality due to starvation. Approaches for wild animal control include lethal and non-lethal strategies. Lethal strategies include trapping, snaring, shooting, and poisoning [67]. Common non-lethal strategies are permanent or seasonal wildlife exclusion fences [68], perimeter fences, double fencing [69], herding, stalling at night, avoiding the accumulation of organic waste, maintaining feeders and feed storages in proper conditions, keeping feed in dry and tightly closed containers, not allowing pets in the production unit, cleaning-up feed spills, and appropriate disposal of carcasses. The use of guard animals such as sheep dogs, donkeys (*Equus asinus*), llamas (*Llama glama*), and alpacas (*Vicugna pacos*) can help discourage invaders [60].

The efficacy of predator control methods is related to predator species and mitigation strategy more than with livestock type. Farmers in Wyoming, USA, considered that the diverse mitigation strategies available were effective in the control of foxes and coyotes, somewhat effective with large carnivores, and least effective controlling avian predators [67]. The use of non-lethal strategies is practical in small-scale farms, while its implementation in large areas could become inefficient. In the USA, the most used non-lethal mitigation measure across different farms sizes are livestock guardian dogs [70]. However, their use should be subject of a cost (acquisition and maintenance) versus benefits (reduction in losses) analysis [70]. The use of donkeys or camelids present lower maintenance costs due that part of their diet is provided by forages grown in the farm. Special care must be given to the control of rats (*Rattus* spp.) and mice (*Mus musculus*), as they can become important reservoirs of pathogens such as *Salmonella*, *Leptospira*, *Yersinia*, *Brucella suis*, *Erysipelothrix rhusiopathiae*, and *Brachyspira hyodysenteriae* [66,71]. Performing frequent movements of the operation is a useful strategy to reduce *Salmonella* infestation [72]. It is important to avoid using cats in rodent control programs due to the risks associated with the transmission of *Toxoplasma gondii* [58,63,65]. Similarly, mammals (including feral and wild pigs) and birds have been identified as reservoirs of African swine fever virus [73], *Salmonella* [72,74,75], and *Streptococcus suis* as the causative agent of meningitis, arthritis, endocarditis, pneumonia, and septicemia in pigs [76,77].

Wild Boar

The rapid expansion of wild boar presence represents a special risk for pasture pigs due to an increase in the frequency of potential contacts. Undesirable mating among domestic and wild pigs and the potential contamination with shared pathogens are the most common threats [78,79]. Wild boars have not only been reported as playing an important role in the transmission of parasites, bacteria, and viruses to domestic animals but also to humans [80–83]. These animals have been identified as potential sources of African swine fever virus [56,73,84], Aujeszky's disease [78,79], brucellosis [78,79,82], *Campylobacter* [80], classical swine fever [85], giardiasis [80], salmonellosis [81], *Streptococcus suis* [77], toxoplasmosis [81,82], trichinellosis [61,82], tuberculosis [86,87], and yersiniosis [81] in domestic animals, and leptospirosis, tuberculosis, hepatitis E, brucellosis, and trichinellosis in humans [56,78,83]. Conversely, Batista Linhares et al. indicated greater probability of contagion of enzootic pneumonia caused by *Mycoplasma hyopneumoniae* from domestic pigs to wild boars [88]. Pathogens can also be transmitted through consumption of contaminated meat, as in the case of bacteria such as *Escherichia coli*, *Listeria monocytogenes*, and *Campylobacter* [80,81] or viruses such as African swine fever [73] and classic swine fever [85].

Appropriate fences help reduce contact between wildlife and livestock [68]. Based on an assessment on risk factors for contacts between wild boars and domestic pigs, pig fences should be higher than 60 cm to avoid intrusions [78]. According to the same authors, breeds such as the Mantgalitza that are most phenotypically and genetically similar to wild boars; thus, potentially more attractive to them, presented a higher frequency of undesired mating than Landrace or Large White sows. Therefore, on farms raising these pigs a wire-mesh external fence should be used in addition to the electric fence to prevent undesired crossbreeding [78]. Conducting biosecurity programs and disease surveillance protocols both for wild and domestic pigs are key to minimize the risk of introduction and transmission of diseases on pig farms in particular against African swine fever, classic swine fever, Aujeszky's disease, and porcine brucellosis [56,79,89].

Exposure to Pathogens (Parasites, Bacteria and Viruses)

Under a grazing environment, pigs are exposed to greater contamination risks with pathogens causative of diseases that can impair their health and welfare, or can be transmitted to humans [25,63,65]. Additionally, the implementation of biosecurity measures and control programs is far more complex in pasture systems [57,90,91]. *Salmonella* and *Campylobacter* were found in soil from paddocks managed with pigs [91]. Compared with pigs in intensive confinement systems, outdoor pig herds have presented a higher prevalence of *Salmonella* [92], *Toxoplasma* [91,93], *Trichinella* [93], *Leptospira Bratislava* [33,57], *Ascaris suum* [94,95], and *Taenia solium* [93].

In Mediterranean areas, the role of extensively raised pigs in the transmission of the *Mycobacterium tuberculosis* complex causing tuberculosis has been established [86,96]. In the Netherlands, Van der Giessen et al. reported higher incidence of *T. gondii* in pigs from free range farms than in confinement (33% vs. 4%). However, no differences among the production systems were observed for *Trichinella spiralis* [97]. Similarly, in Mexico, Ortega-Pacheco et al. found that the risk of infestation by *T. gondii* in farms with less than 400 pigs was 28 times higher than that in bigger farms and reported an association among automatic feeder type and infection risk [98]. According to Wallander et al., access to pasture in Sweden is one important risk factor in pig transmission of *T. gondii* [58]. Pablos-Tanarro et al. found a higher prevalence of *T. gondii* in Iberian sows managed in extensive systems compared to intensive systems [66]. More recently, Castillo-Cuenca et al. reported seropositivity to *T. gondii* in 86% of the Iberico pig farms tested, with higher prevalence in sows than in fattening pigs [65].

Sutherland, Webster, and Sutherland compared information from different countries, and indicated that in the Netherlands pigs managed outdoors showed higher levels of infestation with *Ascaris suum* and *Eimeria* spp. compared to pigs managed in confinement. Nonetheless, the same authors found no differences between production systems in relation to the prevalence of *Oesophagostomum* spp. and *Trichuris suis*. In samples collected in Austria, 75% presented eggs from gastrointestinal parasites (*A. suum*, *Oesophagostumum* spp., Coccidia, and *T. suis*) and 30% of the sampled animals had lice and scabies. At the time of slaughter, 50% of the animals had white liver spots, indicators of previous infections with *A. suum*. In Denmark, 28% of weaned piglets and 33% of fattening animals were infected with *A. suum*, 4% of weaned animals and 13% of fattening animals were positive for *T. suis*, and 20% of sows for *Oesophagostumum* spp. No ectoparasites were detected in these animals [95]. More recently, Vásquez reported incidences of mixed infections of *T. suis* and *Lawsonia intracellularis* in Iberico pigs and their crosses reared in the Dehesa [99].

Some of those pathogens, such as *Salmonella*, *Campylobacter, Ascaris suum,* and *Trichuris suis*, can survive in soil, water, shelters, and huts of pasture environments [91,100,101], and could represent a significant risk of infection [97]. As a strategy for parasite control in pasture systems, it is important to implement periodic parasitology monitoring of the herd [86,102]. Certain management strategies have proven effective in reducing parasite infestations in pasture pig operations. Among them: avoiding the use of moist areas with a tendency to become waterlogged, implementing pasture rotation [72,101], decreasing the stocking density, using forage mixtures (including forages with high tannin concentrations), mixed animal species grazing [103], and integrated use of anthelmintics [57].

Ingestion of Toxic Elements

A threat to the wellbeing faced by pigs managed on pastures is the potential ingestion of toxic plants and mushrooms [33,104]. In the United Kingdom, there have been described pig intoxications and in some cases deaths due to the consumption of ferns (*Pteridium aquilinum*, subspecies *latiusculum* and *atlanticum*) containing toxic and carcinogenic substances [105]. Grazing pigs ingest a considerable amount of soil while foraging [57]. Rivera Ferre et al. reported sow fecal ash concentrations up to 937 g kg^{-1} DM and 450 g kg^{-1} fresh weight of stones [106]. Similarly, Jurjanz and Roinsard indicated that grazing lactating sows ingested on average 0.3 kg of soil/sow/d [107]. This situation could potentially expose grazing pigs to the risk of ingestion of contaminants, including toxic metals that could be found in the paddocks [57]. Toxic components could accumulate in animal tissues such as muscle, liver, and kidneys, and affect animal health; this could also represent a risk for humans consuming meat from these pigs.

Exercise

Compared with other systems, pasture systems offer pigs a greater opportunity to carry out more physical activity [6], which would result in better animal welfare [35,108]. The impossibility of behaving naturally due to confinement, and the privation of environmental stimulation have been identified among the main causes of boredom and frustration in indoor managed pigs [24,39]. Additional potential consequences to lack of exercise are more health related: impairment of the cardiovascular system, and weakness of bones and muscles which frequently cause lameness [41]. However, free-range pigs have been reported to have more frequent and severe osteochondrosis than indoor pigs; nevertheless, these pigs did not show lameness [109]. The greater opportunity of exercise in outdoor systems could have reinforced the joint supportive tissue and contributed to alleviate the pain [109,110]. Furthermore, increased exercise translated into better physical condition in pasture pigs which allowed them to better resist the stress of mixing and the hardships of transport and lairage [111]. Lack of exercise may also have consequences beyond sow welfare such as decreased piglet survival at farrowing [29]. In spite the benefits of exercise, higher physical activity in pastures could be associated with higher energy expenditure [112] and higher nutritional requirements [33] that need to be considered in feeding programs for the sake of grazing pig welfare.

3.2. Animal Genetics

Attaining an appropriate level of welfare under pasture conditions requires adapted and robust animals that are resistant to parasites and pathogens, and that can take advantage of the nutrients provided by pastures [23,113,114]. Prunier et al. discussed the greater influence of genetics in less controlled environments such as in pasture conditions. Traits of importance such as litter size (at birth and at weaning) and pre-weaning survival show heterosis effects (either maternal–crossbred mothers or direct–crossbreed piglets), milk production and number of teats show differences among breeds [23]. In terms of animal genetic improvement, the two options for free-range or pasture-based production systems are the use of pure or crossbred pigs selected for high input systems or the use of local heritage breeds [114]. In most European organic systems, locally adapted traditional breeds are preferred for outdoor systems [110].

Traditional pig breeds are well adapted to local environmental conditions including climate, diseases, parasites, and available feedstuff (forages, acorns, chestnuts, birds, small mammals, and soil fauna); thus, becoming a good option for pasture systems, either as pure breeds or in crossbreeding programs [115,116]. Grazing behavior of pigs resulting from crosses of (Landrace × Yorkshire) sows with boars of the traditional breed, Tamworth, grazed more than the progeny of sows of the same genotype with boars of the improved Duroc breed. Conversely, Duroc crossbreds expressed more frequent resting and no difference in rooting behavior [117]. In addition to their adaptation to pasture conditions, another advantage of the traditional breeds is the quality of their meat, an attribute which has earned them the appreciation of restaurant chefs, artisans, and consumers [118–120]. Compared to modern genotypes, local breeds have shown greater fiber consumption and digestibility [121]. The use of traditional breeds also contributes to the maintenance of genetic diversity in livestock species [115].

The main disadvantage of local breeds is their lower economic performance when compared to modern genotypes, which may lead producers to select breeds showing less adaptability for pasture-based systems. Animal breeding and genetic improvement programs should be oriented toward obtaining a balance among lower inputs and greater output goals [122] without sacrificing important traits for these systems such as adaptation and meat quality. Crossbred pigs selected for outdoor systems displaying desired traits, environmental adaptation, and economic efficiency have been developed by breeding companies [29]. Caution should be taken not to create greater problems through breeding programs [123]. Selection for prolificacy could be a source of stress and reduced welfare for both the high-prolific sows and their litters [124]. Sows with larger litter size have shown increased duration of farrowing and piglet mortality, disparity in the number of teats in relation to a greater number of piglets, lower piglet birth weight, and more competition among piglets [125–127]. In these cases, selection for productivity could be associated with reduced mothering ability which is essential in pasture systems with reduced monitoring and intervening possibilities to support animals. These issues indicate the need to reorient the genetic selection, giving more importance to welfare-related traits such as sow longevity and piglet survival [57].

Despite the unsuitable breeding criteria for conventional pigs to outdoor conditions [31], some European farmers use pigs improved for indoor conditions in pasture systems [110,128]. Röös et al. advised that these animals could not reach their genetic potential when managed on pastures [128]. Additionally, there is increased potential for more frequent and severe joint lesions among these animals suggesting that the leg conformations of modern genotypes are not adapted to the exercise requirements associated with pasture-raising [109,129]. Disease resistance, adaptation to environmental and diets variations, the ability to exploit alternative local feedstuff [114], leg conformation and strength, sow longevity, lean growth, and reproduction rate have been proposed as important traits to be included in selection programs aimed at improving the welfare of outdoor pigs [130]. However, simulation of breeding models for increased welfare (mothering ability and sow longevity) resulted in reduced growth rates for animals raised for slaughter [130]. Nevertheless, sows selected for outdoor production have more robust piglets that show greater pre-weaning survival rates [131]. For animal welfare purposes, genetic selection for litter size should focus on obtaining no more than 12 robust and viable born-alive piglets [125], enhance neonatal survival, and ensuring reduction of intra-litter birth weight variability to improve piglet survival rates [132]. Additionally, selection for maternal behavior (crushing piglets, posture changing at farrowing, piglet-directed aggressions, responsiveness to piglets, and nursing behavior) has been related to piglet survival [132,133]. Aggressive behaviors of pigs are also important for welfare and can be improved by breeding [133]. Breeding programs can moderate aggressive behaviors causing a reduction in tail biting [114]. Chinese Mi pigs were less active and less aggressive than European Landrace—Large White crossed pigs [134]. De Melo et al. compared the behavior of Piau (a local breed) sows to those of crossbreeds (Duroc × Pietrain × Large White and Landrace × Pietrain × Large White) sows in a semiarid area in Brazil. Crossbred sows exhibited more heat stress behaviors and aggressiveness than local sows, suggesting better adaptation to the climate by the local breed [135].

3.3. Expressing Species Specific Behaviors

Pasture systems are more favorable for animal welfare than confinement systems [12,35,49,136], because pigs have a better chance of expressing their species behavioral habits, such as organizing in groups and interacting with their peers, exploring the habitat, foraging, grazing, rooting, and wallowing in the mud, when compared with indoor-reared pigs [136]. Behaviors such as grooming and play are self-rewarding and can be considered an ethological need which ensures welfare of the animals. Inability to express ethological behaviors as a result of environmental restriction or pain can lead to distress and impact the wellbeing of the animals [137], which results in the appearance of stereotypes and other abnormal behaviors [138] that can be considered indicators of reduced welfare [5].

Differences in piglet behavior (during nursing, at weaning, and post-weaning) have been observed in indoor and outdoor systems. Indoor piglets showed more agonistic behaviors (belly-nosing, other oral–nasal interactions) towards mother and littermates than outdoor piglets. Outdoor piglets, in the other hand, interacted with the sows less often and were more active walking and exploring paddocks. Indoor-managed sows interacted with the piglets all the time, whereas outdoor sows reduced the time they dedicated to the piglets from 86% the first day to less than 30% for days 12 and 19 after farrowing. Even though no differences were found among outdoor and indoor sows during active time, outdoor sows spent more time standing, walking, and exploring their surroundings. The observed behavioral differences could be attributed to the distinctiveness of the environments, including space availability and complexity [139].

The limited space and the existence of artificial social structures characteristic of confinement systems can negatively impact social interactions; thus, generating aggressive behaviors [25]. Higher number of skin scratches were registered in indoor-kept piglets, which displayed more resting, drinking, moving, aggressive, and fighting behaviors, whereas outdoor pigs showed higher frequency of investigative and social–play behavior, lower body wounds, and greater weight gain [140]. Studying the behavior of Iberico pigs reared in intensive or extensive production systems, Temple et al. observed a higher incidence of both positive (nosing, sniffing, licking, and moving gently, 10.0% vs. 2.3%) and negative–aggressive behavior (biting or any other conflictive behavior, 5.1% vs. 1%,) in intensively-managed pigs. Their analysis showed that pigs managed in extensive systems are more entertained and vivacious, in their words "happier and content". These authors did not detect differences in other behaviors, such as exploratory behavior, or human and animal relationship as a consequence of the rearing production system [141]. Similarly, Parrini et al. observed a reduction in aggressive behavior in Cinta Senese pigs managed outdoors when compared to pigs of the same breed that were reared indoors [34]. Because pasture ecosystems are so diverse, it is possible to provide grazing pigs with more opportunities to further display their vast inventory of specific behaviors in comparison with indoor-reared pigs; hence, reducing aggressiveness and manifestation of stereotypes [57]. In addition, pigs managed on pastures have more room to escape and to move away to avoid aggressive behavior from other pigs.

3.3.1. Rooting

Rooting, one of specific behaviors expressed by pigs on pasture, has been linked to foraging, thermoregulation, and nest-building [35]. Age, sex, genotype, and novelty are some factors related to the expression of rooting behavior [24]. Outdoor housing of pigs encourages the expression of natural behaviors such as rooting and contributes to controlling stressful reactions, both factors of importance for welfare [142]. Indoor-confined pigs with reduced possibilities to root have shown increased abnormal conduct, like fighting and biting, suggesting substitution of behavior [143]. Nevertheless, the use of environmental enrichment strategies proved effective to increase activities like exploring, foraging, playing, and social interactions; thus, improving animal welfare and performance of indoor-managed pigs [24]. Feed restrictions and irregularities in daily feeding management have been associated with hunger and higher rooting frequency [24]. Moreover, pasture conditions such as soil moisture [34,35] and low environmental temperature, have been related with increased rooting behavior [35]. However, rooting may represent a risk of infections with pathogens because of the increased risk of ingesting *Salmonella*, *Campylobacter*, and *T. gondii* oocysts from contaminated pasture and soil [58,91]. Even though rooting is a positive exploratory and feeding behavior [144], it has also been associated with sward deterioration and negative environmental impacts. The creation of bare soil areas through rooting can lead to runoff and erosion [21]. Wet and muddy conditions are frequent during winter in paddocks managed with high stocking rates where the impact of sows rooting behavior prevent the recovery of the vegetation [30].

3.3.2. Wallowing

Wallowing (covering the body with mud) is an important behavior for swine and possibly an indicator of pig welfare itself; it serves multiple functions such as thermoregulation/cooling, sunburn protection, ectoparasite control, social and mating behaviors [145]. The cooling effect of wallowing happens when the water evaporates from the skin, which increases when the coating is composed of mud instead of water because it takes longer for the water in the mud to dry-out [146]. Reductions up to 2 °C of body temperature have been reported in response to wallowing [35]. The layer of mud acts also as a barrier to the sun ultraviolet rays; thus, preventing sunburn [20] and protects the skin from biting insects and parasites such as flies, ticks, and lice [145]. Indoor confinement systems prevent the manifestation of this behavior [147]. Nevertheless, the expression of this behavior could also represent a risk to the welfare of pigs. The use of wallows has been linked to reproductive [148] and health issues [149,150]. *Salmonella* [72,149,151], *E. coli* [149], and *T. gondii* [58] have been isolated from wallows. Recommendations for a safe use of wallows to reduce the infestation risk include implementing individual-use wallows, positioning wallows away from drinking water sources, and avoiding standing water [22]. In addition to natural shade from trees in pasture systems alternatives to thermoregulation like nebulizers and sprinkler systems could be considered when appropriate. [152]. Effective reduction in heat stress has been observed from pasture pigs when foggers were installed in shaded areas [20].

3.3.3. Excretory Behavior

Pigs, both in semi-natural conditions and in confinement, differentiate areas within the available space and designate certain sections for resting, eating, and defecating. In general, pigs avoid the use of certain areas (nest, rest/lying area, close to feeders, waterers, and wallows) for their excretory behavior [153]. Therefore, from an animal welfare standpoint, it is important to provide sufficient space so that they can differentiate excretory areas from the rest. Lack of enough space could force the animals to lay in the soiled area, becoming a source of stress and a potential health risk. In pasture systems, the manifestation of the eliminatory behavior could create soil nutrients hot-spots in the preferred dunging site [21]. These manure-concentrated sites present the risk of irregular accumulation of parasites eggs in the paddocks, as have been observed for *A. suum* eggs [154]. Periodic movements of the shelters, huts, feeders and drinkers, the frequent allowance of new grazing areas, and the implementation of rotational stocking systems have demonstrate effectiveness in improving the distribution of excreta in the paddocks; thus, reducing the risk of contamination with pathogens [20,21]. Similarly, the provision of rooting areas has been used as a strategy to reorient the excretory behavior toward specific areas of the paddock [155].

3.3.4. Nest Building Behavior

Maternal behavior is appreciable even before farrowing through modifications of social and feeding behaviors. In pastures as in the wild, two to three days before farrowing, sows initiate a series of behaviors, including the search of a secluded place to nest, set up a nest, and reduce food intake [2]. Instinctively, they use grasses, branches, vines, and leaves as nesting material. Once the nest has been built, the farrowing can start. The expression of this behavior to protect the litter from environmental conditions and potential predators [156], has been related with shorter farrowing, better nursing, enhanced maternal behaviors, more colostrum, higher fertility rate, less stillbirth, and healthier and larger litters [127]. Conversely, sows managed in farrowing crates cannot display this behavior. Prolongation of the duration of farrowing was observed in sows that were abruptly confined before parturition [157]. Activity and locomotion could be important for the full expression of normal behavior of pre-parturient sows [158]. Additionally, environmental conditions influence the expression of specific behaviors in the period from pre-parturition to lactation that could impact sows' welfare and even more piglets' survival [159,160].

These observed behaviors reveal the advantages of outdoor pasture systems over confined ones when it comes to animal wellbeing, for the needs of the sow and piglets are better met in pasture systems [161]. Sows are moved to the farrowing–nursing paddocks (either individual or collective containing farrowing huts for each sow) 7 to 10 days before farrowing, allowing them to become familiar with the environment and expressing nesting behavior [60]. Sows are allowed to leave the hut, but the piglets are kept inside for the first 10 to 14 days. This system permits the display of maternal behavior and to strengthen the mother–piglet bonds, favoring a better early lactation [161]. Sows unable to express this normal behavior due to confinement or to the lack of nesting materials will become stressed, which in turn will affect their welfare and that of their piglets [4,103,156]. Furthermore, these sows show greater indifference to the calls of the piglets and a more marked tendency to display aggressive behavior toward them [2] and other abnormal behaviors, such as bar biting, trough-biting, vacuum chewing, and excessive drinking [1]. Relocating pregnant sows outdoors one week prior to farrowing resulted in a greater live-born piglet mortality, which was attributed to more time spent foraging outside of the huts before and after farrowing. Providing sufficient time for the sows to isolate themselves adequately reduced the negative effects on piglet mortality and growth rates [23].

3.3.5. Social Behavior

Pigs are social animals [24] with a strong hierarchical and stable organization formed since birth. Their hierarchy structure is mostly based on age and body size [2]. In the wild, most pigs' activities are conducted in groups [29,162], whose size relates to available resources [163], and include young and adult animals [147]. In pasture conditions, congregating stimulates nursing, foraging, and can provide protection against predators. Cinta Senese pigs and their crosses on pasture, preferred to conduct their activities in groups most of the time, particularly during morning hours [34]. In groups, dominance relationships between animals are established with subordinate animals having limited access to resources such as feed, water, preferred space, and receiving most of the aggressions [164].

The social status of pregnant sows affects their behavior, with dominant sows being more active, showing more aggression, and displaying higher use of straw, compost, and cotton ropes available in the pen. Subordinate sows are more frequently ousted from the use of the material available [165]. Most negative social interactions in dry sows are the result of competition for feed and social instability while new hierarchies are formed after mixing with unfamiliar pigs [30]. Reduction in aggressive interaction relates to size of the group of sows; lower aggression has been observed both in small groups (less than 9) or large group (more than 25) [30,31]. Increasing the space allowance offered to pregnant sows (3.0 vs 2.25 m^2 per sow) can reduce the number of one-way aggressions and the number of injuries following grouping [166].

Discrepancies in the social behavior of pigs reared in indoor and outdoor systems are also influenced by intrinsic attributes of the systems, including environmental temperature [139] or muddy pastures condition [144,167]. Confined indoor pigs cannot express social behaviors, which leads to psychological distress [168] and inadequate social comportment. The competitive behaviors are mainly constituted by pushing, head thrusting, and attack sequences that may culminate in bites [2], or more harmful behaviors like tail biting [140,142] or cannibalism [31]. Triggers to tail biting in confined animals can include: high animal density, poor water and feed supplies, competition for these resources, incorrect or fluctuating temperature levels, inadequate ventilation, noise, air currents, high levels of dust and harmful gases (ammonia), lack of opportunities to escape from dominant animals, genetic factors, lack of environmental enrichment (such as materials for rooting), and also general health problems [144,167,169,170].

In pasture systems, pigs are subject to lower social distress, have greater space allowance, and a more diverse environment. In these systems, the occurrence of tail biting indicates the existence of factors that predispose the manifestation such as genetic factors, respiratory issues, diet insufficiencies, and/or pastures muddy conditions [168,171]. Even though outdoor systems are not exempt from aggressive behaviors, their frequency and intensity are lower and cause lesser lesions [168,172]. Lower prevalence of tail lesions, severe body scars, and tail biting damage was reported in pigs reared outdoors than in pigs managed in the combined indoor–outdoor, or in the indoor system [28,110]. To minimize aggressive behaviors in outdoor systems efforts should be oriented to find better ways to reduce the impact of the environmental temperature on the animals [28]. Some strategies have been tested to prevent tail biting in intensive systems by the provision of manipulable substrate [169], and the implementation of exploratory feeding strategies [172], and those have proven effective in reducing aggression and skin wounds. In pasture systems, ample space and environmental diversity contribute to lower tail biting problems [173].

3.3.6. Grouping and Regrouping—Mixing Animals

In indoor-confinement systems, the practice of mixing unfamiliar pigs such as growing pigs or sows is common. However, this practice can also be conducted in pasture pig systems at weaning, at the beginning of the growing–finishing period, when organizing homogeneous groups, within the groups of gestating sows, and during transport. This procedure leads to aggressive interactions resulting in stress, aggressions, skin wounds, lameness, and impaired welfare [50,174,175]. Moreover, frequent mixing could cause chronic stress [176]. Mixing implies the formation of new social hierarchies with potential changes of roles (dominating–subordinate). Piglets reared outdoors during lactation showed lower level of aggressive behavior and lesser lesions when mixed after weaning in comparison with indoor managed pigs. These differences have been attributed to special skills acquired when interacting with same age piglets from other litters and with older pigs, or to a better capacity to handle new situations as a consequence of exposure to a more complex environment [50]. In European organic sow herds, issues after mixing have been observed, such as social competition for feed and resting space, and aggressive behavior culminating in skin and vulva lesions [30].

Implementing appropriate management strategies could avoid the negative consequences of grouping and regrouping [177] both in pasture and in confined systems, because it is advisable to maintain social relationships as stable as possible [31]. When grouping sows, it is recommended to manage a small number of sows, mixing sows of the same parity, and conducting the mixing in areas with ample space [30]. Other practical suggestions include mixing animals at the end of the day, after feeding, increasing feed offer of standard diets, feeding diets high in fiber [171], and spraying animals with scented, odor-covering solutions [178,179].

The production system can also impact the level of aggressions, frequency, and duration. Fighting episodes lasted longer in indoor-confined pigs, whereas outdoor pigs showed lower levels of aggression. In outdoor pigs, the level and the manifestation of the aggression could have been modulated by social behavior lessons learned through early in life interactions with unfamiliar pigs. Indoor-managed pigs displayed indicators that pre-slaughter mixing was more physically stressful for them than for outdoor pigs. For niche production systems, it could be easier to maintain pigs in their natural social groups, thus minimizing mixing practices and their impact on welfare than in indoor-confinement systems [111].

3.4. Management Practices

Implementing appropriate husbandry practices reduces stress among animals; thus, guaranteeing health and welfare, and ideal productive performance [147]. A management program for grazing pigs must take into account such aspects as climatic conditions, available area, soil characteristics, and producer skills and abilities [64]. Management should integrate elements related to housing, feeding program, grassland management, herd organization, selection and breeding plan, reproductive program, and disease prevention [22,62]. Mistakes in the implementation of some of these management practices may cause a decrease in animal welfare [62]. Moreover, incorrect handling could cause stress [177] or be the trigger for pain [137]. Additionally, inadequate handling, housing, equipment, and mixing animal conditions could stimulate the manifestation of aggressive behaviors, and ear and tail bites that negatively affect wellbeing. It is important that animal caretakers receive appropriate training to avoid unnecessarily stressing the animals [57].

3.4.1. Painful Interventions

The typical management of pigs involves the routine execution of surgical procedures, including ear notching, castration, tail docking, teeth clipping, and tusk trimming, without implementing any kind of pain relief (either the use of anesthetics or analgesics). These procedures cause physiological and behavioral changes in pigs in response to suffering and could lead to other ailments such as lesions, abscesses, and neuromas, leading to chronic pain and acute stress [180]. Some of these interventions also prevent the manifestation of species-specific behaviors, compromising health and welfare. The need to find more animal-friendly management alternatives has led to testing different options [180–182]. For example, the use of tattoos, plastic tags, and electronic tags serve as less painful alternatives to ear notching identification [18,181] and instead of using painful injections to deliver medication, the latter can be administered orally, mixed with feed.

Castration is performed in male pigs to control aggressiveness, undesirable mating, and pork "boar taint" (unpleasant odor in entire male meat). The method most frequently used is the surgical elimination of testicles in pigs of young age, which is painful. In most farms, castration conducted without any anesthesia or analgesia, results in pain and impaired welfare for pigs. Some alternatives to minimize the impact of surgical castration have been under evaluation [31,183]; among them, the use of local anesthesia [18,184], immuno-castration (using pigs immune system to produce antibodies against its own reproductive hormones) [18,185], and the production of intact male pigs (marketing pigs before they have reached sexual maturity at approximately 100 kg) [18,186]. The proposed alternatives present advantages and disadvantages that need to be considered carefully. The cost of combined anesthesia and analgesia makes the practice inaccessible for most farmers [187]. An objection to the use of intact males would be the increased stress due of aggressive and mounting behavior during the finishing period [187]. Contrastingly, good results can be obtained by employing immuno-castration with pigs managed in different housing systems [188]. However, economical comparisons conducted in Germany showed that barrows performed better than boars and immunocastrates [189]. Castrated pigs reared in enriched environments displayed lesser agonistic behaviors, but were harder to manage during saliva sampling, whereas in these environments intact males showed decreased feeding behaviors [190].

Reduction in skatole level has been attained through certain feeding strategies such as ad libitum feeding of intact males [183], addition of fermentable carbohydrates such as sugar beet (*Beta vulgaris)* pulp, high amylase barley (*Hordeum vulgare)*, chicory (*Cichorium intybus)*, inulin (>6%) and raw potato (*Solanum tuberosum)* starch (>20%) [191–193], and dietary supplementation with plant extracts containing herbal essential oils with antimicrobial activity and tannin-rich extracts found in plantain (*Plantago lanceolate)* [193], Jerusalem artichoke (*Helianthus tuberosus*) [194], and lupins (*Lupinus angustifolius)* [193]. In addition to feeding strategies some management practices (avoiding stress, maintaining clean pens, low stocking rates, sex grouping, limiting re-grouping, providing sufficient access to water and feed, and fasting for more than 14 hours prior to transport) also contributed to reduction of skatole [183]. Based on the high heritability index of androstenone production and its accumulation in fat tissue [195], Switzerland, Belgium, Germany, and France have recently oriented their efforts toward genetic selection of individuals with lower androstenone and skatole concentrations in pig dorsal fat. As a result, some Pietrain boars are being marketed as low risk for boar taint [196]. Additional factors that influence androstenone and skatole levels are the size of the groups, mixing strategies, and slaughter weight.

Another practice pigs are routinely subjected to in commercial farms is tail docking, which is conducted to prevent future tail bites. Tails of one-week-old piglets are surgically removed without the use of anesthetics [197] causing pain and damaging the physical integrity of the animals, and complications result in spinal abscesses. It is necessary to compare the negative impacts of tail biting to those of tail docking to decide the convenience of performing the practice [172]. Castration and tail docking are elective procedures and are not conducted routinely in all pasture pig systems. For example, in many pasture systems tail docking is not performed, and castration is not conducted in many pig farms in the UK and Australia. Nevertheless, in other countries market-driven forces influence farmers' decisions to keep performing the procedures.

In pasture systems, the maintenance of the vegetative ground cover is a key condition to minimize environmental issues [21]. To reduce the damage that pigs cause to vegetation and soil while rooting, animals are fitted with metal rings placed in their noses which decrease rooting by causing discomfort. The use of nose rings, while causing pain, inhibits a range of functional activities including rooting, and causes chewing in a vacuum and digging in the ground with the front legs which suggests compromised welfare [29,198]. Alternatives to nose rings have been employed with different degrees of success. Some examples are the use of forages species that could withstand and recover from rooting, reduction in stocking rates, implementation of rotational stocking systems, manipulation of edible substrate-silage [199], and provision of root crops [200].

3.4.2. Weaning Age

Weaning is a stressful event for both sows and piglets [18,139]. It has been reported that weaning impacts the structure, morphology, and functioning of the intestines, the immune response of piglets, feed intake, growth rate, morbidity, and mortality indexes [201]. Weaning is a gradual process that would end at approximately 17 weeks of age in the wild [202]. The way weaning is handled varies among production systems [50]. In indoor-confinement systems, weaning is frequently conducted abruptly between 3 and 4 weeks of age [203]. Conversely, the minimum weaning age is 40 days in most organic systems; however, in some countries, older ages are stipulated in national standards. However, weaning at 40 d could be early when compared with semi-natural conditions, and still lead to physiological repercussions [50]. Weaning at an early age interferes with the normal development of pigs and results in stressed pigs having difficulties adapting to new environments [173,203]. The occurrence of clinical problems related to the post-weaning multi-systemic wasting syndrome could be decreased by implementing a late weaning [50]. Hotzel et al. indicated that weaning age impacted the behavior of piglets reared in outdoor systems, which showed more stressful responses when weaned at three weeks than at four weeks of age [204].

Several factors can influence the welfare of pigs during the weaning stage, mixing, rearing conditions, nutritional disorders, changes in health status, and aggressive behaviors [50,205]. Oostindjer et al. reported the importance of allowing teaching–learning interactions between piglets and sows to reduce post-weaning stress, the fasting period, diarrhea, and the effects that these factors can have on post-weaning productive performance [203]. Weaning older piglets allows the introduction of creep feeding; thus, minimizing the nutritional challenges piglets have to face during this period [206]. Delaying weaning to at least six weeks of age can also decrease negative impact on the wellbeing of piglets by increasing immunity and decreasing the transmission of diseases [11]. The economic benefit of late weaning has been discussed [18,207] but it seems advisable to consider that long lactations could represent an additional effort for the sows, and can affect their body condition, their welfare, and the following reproductive cycle [18]. Therefore, it is important to periodically monitor the sows' body condition [25]. However, Kongsted and Hermansen reported that it is possible to maintain sows body condition even in seven-week long lactations [208].

Differences in the post-weaning behavior of sows and piglets and their social interaction have been associated to the rearing system. After weaning, piglets from confinement presented higher frequency of belly-nosing, aggressive interactions, and reduced feed intake [139]. Conversely, outdoor piglets were more active, walked, ate, and explored more, and developed post-weaning adaptation mechanisms (lower frequency of nursing and greater solid food intake), leading to less post-weaning stress [139]. The differences observed among the piglets were a consequence of the social interactions between the sows and their piglets. Indoor piglets had a more frequent and close interaction with their mothers, whereas outdoor sows had more control of the frequency of nursing resulting in a lower level of interaction with the piglets which stimulated piglet solid feeding and exploratory behaviors. Additionally, the more diverse, spacious pasture environment and greater possibilities to conspecific interaction equipped the outdoor piglets to deal better with the stress of weaning [139]. During weaning and mixing day, outdoor-raised pigs were scored as more passive while those raised in confinement received a more inquisitive grade. Outdoor piglets ate more, whereas the confinement-piglets invested more time investigating their surroundings. These differences could be consequence to confinement leading to neophobia, conflicted affective states, and motivation for exploration. The weaning behavior could reveal piglets' physical and physiological ability to manage the challenges imposed by their new environment and the impact on their social development, which subsequently affect their responses to stressful environments [209].

3.5. Feeding Management

Grazing pigs have higher nutritional requirements to compensate for higher thermoregulation energy costs and for greater exercise in pastures. Therefore, seasonal nutritional adjustments are necessary up to 15% increase of the diet energy in colder climates [39]. However, most nutritional requirement tables have been estimated for pigs housed indoors, which could lead to underestimating requirements for outdoor pigs. Necessary corrections to the amount of feed offered per animal need to be made according to live body weight and extreme environmental conditions.

In pasture pig systems, forages can be included as part of the diet as sources of energy, amino acids, vitamins, minerals, and trace elements [37,39,106]; thus, contributing to a reduction of the feeding costs. Forages contribute also to gut filling; thus, helping to reduce hunger sensation in restricted-fed pigs, and can decrease constipation and gastric ulcers [30,39]. Older animals are better fit to utilize forage fiber [121]. The nutritional contribution of pastures to pig diets relates to the vegetation species present, the amount of forage available, vegetation nutritional composition, and pig voluntary intake [39]. Grazed vegetation intake has been estimated to 0.1 kg DM/d for growing pigs that had access to supplemental feed ad libitum, and 2.0 kg DM/d for dry sows in restricted feeding programs. This intake could fulfill approximately 50% of the daily maintenance energy requirement for dry sows, but less than 5% of growing pig requirements. The nutritional contribution of soil and soil fauna should also be considered [39]. The quantity and quality of supplemental feed required to meet the nutritional maintenance and production needs of each animal category is related to management [57]. Imbalances in the formulation of rations can cause digestion problems and compromise animal welfare [31]. The use of alternative feeds could lead to unmet nutritional requirements and could contain anti-nutritive factors [30]. Producers and caretakers should be aware of the greater risk of feed contamination with pathogens and mycotoxins [31,39]. In pastures, forage availability in terms of both quantity and quality, follow a seasonal pattern related to precipitation and temperature [37]. This seasonal configuration could produce irregular provision of feedstuff and impact animal welfare and productivity; thus, supplementary feed should be adjusted to overcome this issue [20]. During forage scarcity periods, the possibility of livestock ingesting toxic plants increases [210].

Competition for feed could generate stress and fighting, these situations may go unnoticed and lower-ranking animals may not receive the nutrients they require [17,25]. Animals that receive supplemental feed free-choice could tend to minimize forage consumption. A feeding strategy designed to encourage greater forage consumption consists of restricting the amount of supplemental feed offered to the pigs. However, the growth of pigs could be impacted under feed restrictions greater than 20% of their maintenance level [21]; thus, becoming a potential threat to their wellbeing. When finishing pigs grazed on alfalfa or grass and received restricted diets at either low or high protein levels, Jakobsen, Kongsted, and Hermansen found that pigs on alfalfa grazed more than those on grass. Additionally, greater rooting was observed in pigs on a low protein diet and more frequently under grass grazing. The daily weight gain and feed efficiency of pigs were lower in low protein diets than in high protein diets. However, the weight gain and feed efficiency of pigs in low proteins on alfalfa was greater than those on the same diet and grazing on grass [211]. Restrictions greater than 20% of the maintenance level lead to much greater rooting and foraging behavior, while supplementation of vitamins and minerals had no effect [117]. The damage to vegetation cover could lead to potential welfare issues already mentioned and environmental issues [21]. Feeding restrictions have also been used to manage the fatty acid profile of Iberian pigs before the traditional "Montanera" period, a requirement for traditional Iberico cured meats. However, Lopez-Garcia et al. warn that feeding stress and potentially impaired welfare could result from a restricted diet maintained for a long time (up to a year) during the "pre-Montanera" phase [212].

The nutrition of the sows during the gestational period influences fetal development, birth weight, and colostrum and milk production; thus, contributing to piglet survival [43]. Gestating sows under feeding restriction programs to avoid obesity [144], could alleviate hunger sensations by grazing the forages available in the paddocks, and thus reduce aggression episodes and consequent leg injuries and skin lesions [27,29]. The display of sow abnormal oral behaviors show greater relationship with the restricted feed strategy and the resulting hunger, than with the production system [30,39]. Although sows tend to spontaneously reduce their intake, providing a high level of feed during the last day of gestation was related to heavier piglets and fewer problems for the sows [31]. The feeding management (diet composition, digestibility, feeding strategies, and feeder design) implemented before and after weaning could affect the weaned piglets' welfare-response; this is the reason why it is important to ensure early post weaning feed consumption [50]. The peak of sow milk production happens three to four weeks after farrowing. Following this point, it is beneficial to provide access to creep feeding to ensure the piglets are receiving the amount of nutrients required [23].

In general, feeding animals during the coolest time of the day, increasing the number of feedings, and using liquid feed are convenient strategies to overcome the reduced appetite shown by pigs during hot weather. Throughout hot periods, it is convenient to make adjustments to the diets, increasing the energy density, reducing the fiber concentration, and providing abundant water. Additionally, increase growth performance of indoor pigs under heat stress was observed when pigs were fed either a low protein with low fat diet or a high protein with high fat diet [213]. A daily water supply of adequate quality (dissolved salt and microbiological) is critical to the whole herd on pastures [39]. Ensuring that piglets after four weeks of age or during occurrences of diarrhea have access to water prevents dehydration and is key for health and welfare [23]. Reduced intake of feed in lactating sows has been related with low flow rates of water from drinkers [39]. The supply of water during the warm season is paramount, but shortage of water during winter as a consequence of frozen pipes and drinkers could also pose a problem and should be avoided.

An indicator of the nutritional and health status of the animals is body condition score, which can be related to insufficient feed on offer, competition for access the feed [214], and to over-feeding. It is advisable to monitor the entire herd, but especially the sows to guarantee adequate body condition at the time of farrowing and weaning. Animals at the bottom end of the body condition scale may have a low level of wellbeing. Additionally, sows in better condition can show lower levels of aggressive behavior [30,39]. Body condition monitoring is important to avoid malnutrition which can happen frequently in sows managed outdoors [25]. For example, 3% of Mallorcan Black pigs (a Spanish heritage breed) managed on pastures and receiving no feed supplementation showed poor body condition (visible hip bones and backbone), whereas among pigs receiving cereal supplementation only 0.4% exhibited a low score [215]. The comparison of four feeding methods (individual, group-feeding indoors, group-feeding outdoors, or electronic sow feeding) in different pig farm systems from the UK and The Netherlands did no show differences among the body condition scores recorded for pregnant and lactating sows [214]. However, the loss of body condition due to extended lactations and insufficient nutrients supply was indicated as a frequent ailment among organic lactating sows in the UK and Denmark [30,39].

3.6. Health Management

Health issues have been identified for both indoor and outdoor systems, with differences in the incidence of the different issues. Though, it is possible to deal with those problems by implementing appropriate management strategies [6] so that implications on production and animal welfare can be minimized. An open and ventilated environment and lower stocking densities could contribute to lower respiratory problems and enteric diseases registered in outdoor pigs [29,57,62]. Lower incidence of mastitis, metritis, and agalactia (24.5%), limb lesions, torsion or distention of abdominal organs [32], tail damage and body scars [28], tail bites, belly nosing, and aggressions [216] have also been reported. However, in Hungary, outdoor systems have been associated with a greater incidence of deaths caused by urogenital diseases, heart failure, and locomotor problems than deaths reported in indoor systems [217]. Additionally, in outdoor systems most sow deaths occurred in the periparturient period leading to lower average parity at death than in indoor systems, where most deaths happened during lactation [217]. Similarly, Austrian organic sow herds also reported incidence of urinary tract infections and gastric ulcers [30]. Lameness due to hoof lesions and abscesses was identified as common health issues in European organic sow herds, with some countries expressing more concern about this issue than others [30].

Skin lesions and scars as a result of sunburn, ectoparasites or scratching [30,216], arthritis [218], severe osteochondrosis [109], lameness [28,30,218], and parasitism [57,218] are more frequent in grazing pigs [30,216]. There is a greater prevalence of arthritis-osteochondrosis, tail lesions, bone fractures, skin lesions, liver spots, septicemia, and abscesses in pigs from outdoor systems (both conventional and organic) when compared to pigs from indoor systems. Nevertheless, there is a lower probability for hernia, leg swellings, and hoof abscesses for outdoor pigs [11]. In a comparison of European organic (indoor, outdoor, and combined indoor–outdoor) pig production systems, Leeb et al. found in general few health and welfare issues, reporting no ectoparasites, shoulder lesions or pigs needing hospitalization, and less than 5% tail lesions and conjunctivitis. However, outdoor-managed pigs showed a lower incidence of weaning diarrhea, respiratory problems, and sows' lameness compared to the other two systems [110]. According to Kongsted and Sørensen, implementing weaning at a later age and providing greater space are advantages of pasture systems that have a beneficial impact on the animals, increasing their immunity and consequently decreasing disease prevalence in these systems [11].

Ectoparasites such as *Haematopinus suis* (lice), *Sarcoptes* (scab mites), *Tunga penetrans* (chigoe flea), *Cochliomyia* (blowflies), and *Dermatobia hominis* (bot fly) have been identified in Brazilian intensive pasture pig systems, whereas *Eimeria, Balantidium, Isospora, Oesophagostomum*, *Strongyloides*, *Ascaris,* and *Trichuris* were some of the reported endoparasites [102]. Ticks (genus *Ornithodoros)* play an important role in the transmission cycle of African swine fever [56,73]. In the Cerrado savannas (Brazil), mowing the vegetation was an effective strategy to reduce the infestation of ticks (*Amblioma cajennense* complex) in pasture-raised pigs by breaking their life cycle [219]. The main groups of parasites registered in suckling pigs in Poland were Coccidia and *Strongyloides*. Conversely, in fatteners *A. suum* and *T. suis*, and in sows *Oesophagostomum* spp., were more common [220]. Similarly, Leeb et al. reported infestations with *A. suum* and *T. suis* in weaned piglets managed on pastures [50]. Evaluating European pig systems, Edwards et al. indicated the presence of gastrointestinal parasites as *Oesophagostomum* spp., *Hyostrongylus rubidus,* and *Eimeria* spp., and ectoparasites as *Haematopinus suis* and *Sarcoptes scabiei* in organic sow herds [30].

A marked seasonal survival of *A. suum* eggs on pastures and seasonal variations in pig reinfection rates were observed in Denmark. The eggs deposited during the summer months showed lower survival rates in comparison with those deposited during fall [221]. Pastures managed with low stocking rates and low rotation frequency could maintain the vegetation ground cover, which could facilitate the survival of *Oesophagostomum* spp. infective larvae; thus, benefiting parasite buildup [30]. Pig manure can harbor different pathogens (*Salmonella* sp., *Escherichia coli*, *Clostridium* spp., *Mycobacterium* sp., *Enterococcus* spp., *Streptococcus* sp., and *Staphylococcus* sp.) and cysts, eggs, and/or larvae of parasites (*Ascaris* spp., *Oesophagostomum* spp., *Trichuris* spp., *Strongyloides* spp., *Isospora* spp., *Eimeria* spp., *Giardia* spp., *Balantidium* spp., and others) that could persist in pasture environments (soil, water, and vegetation). Manure provides protection against UV radiation, desiccation and elevated temperatures while supplying nutrients. Pathogens can remain viable under the appropriate conditions for many years [222]. Soil texture, organic matter concentration, temperature, moisture, pH, nutrient availability, and competition with indigenous soil microorganisms are factors affecting pathogen survival. In general, cooler temperatures and high moisture favor longer survival. For example, the survival of *Oesophagostomum dentatum* was limited by winter [154]. Eggs, infectious larvae, oocysts, or sporocysts can survive for a long time, even years, as nematodes such as *Ascaris* spp. (up to 9 years), *Trichuris* spp. (up to 11 years), and coccidial oocysts [30,223]. Due to pig excretory behavior, pastures presented an irregular distribution of *A. suum* eggs with the presence of hot spots. The implementation of rotational systems resulted in control helminthic infestations in pasture pig herds [221]. Additionally, it was found that stocking rate influenced the *Ascaris suum* infestation level of pastures [221,222].

Piglet mortality from farrowing to the weaning period is an important issue in pasture pig production [29,127]. Nursing piglet mortality was lower in combined outdoor–indoor and outdoor systems when compared to indoor systems [110]. In outdoor systems, piglet mortality has been associated with factors related to the environment [41,44,224]. Most deaths are the consequence of sows crushing piglets (causing injuries and even death), hypothermia, and starvation, and often happen during the first week of life [43,49,127]. Another important threat to health during this stage is diarrhea (*Clostridium*, coccidiosis (*Isospora suis* and *Cryptosporidium* spp), *E. coli,* and occasionally rotavirus). Post-weaning diarrhea is considered a consequence of management (multifactorial origin) due to the weakening of the immune system resulting from post-weaning stress [62,71]. Diet plays a central role in the prevalence of this health problem [31], which has also been related to viral and bacterial causes (Rotavirus, Salmonellosis, *E. coli*, *Campylobacter*, *Brachyspira hyodysenteriae*, and *Eimeria* spp.) [62,203].

No differences in mortality rate of live-born piglets have been found among indoor and outdoor; however, lower frequency of stillbirths was reported for outdoor pig systems [131]. The main cause of piglet (0–4 day old) death in organic herds in Denmark was sow crushing and starvation specially in multiparity sows [44]. Higher mortality was observed in larger litters, and was related to long farrowing, weight heterogeneity, presence of stillborn [23,41], decreased colostrum and milk intake, and behavior of piglets (by staying close to their mothers) [23]. The likelihood of piglet survival has been linked to piglet weight and body shape, and their ability to suckle colostrum [12,43]. To reduce the mortality rate, it is important to provide an appropriate microclimate at farrowing time.

Appropriate health status in outdoor herds can be achieved by the implementation of practices like grazing management, genetic selection for disease resistance, adequate feeding program, and the preventive use of plants and fungi [62]. An appropriate grazing management oriented toward ground cover maintenance, implementing pasture rotation, periodical movement of equipment (hut, shelters, feeders, and drinkers) and adopting appropriate stocking rates (in the range of 15 sows and 20 pigs/ha) [21] can help in disease control in pasture pig systems. Additionally, implementation of alternative strategies to prevent infection in organic systems could include the design and maintenance of huts, shelters, pens, paddocks that adapt to the natural behavior of pigs, supplying nutrients according to the requirement of pigs, and the use of herbal treatments [225]. The role of performing huts and shelters movements along the paddocks, and pasture rotations to reduce the contamination with endoparasites and coccidias—*Isospora*, has been emphasized by Prunier et al. [23]. In Denmark, encouraging results have been reported for the control of *Oesophagostomum* spp. through the implementation of better sanitary practices and rigorous pasture rotation [30].

Periodically monitoring, identifying, and isolating pigs needing to be treated in outdoor systems can be complicated, and could affect animal health and welfare [11,33,57]. In outdoor systems, it is possible to underestimate clinical issues and leg disorders because of the complexities in the diagnosis highlighting the importance of the management strategies in the different health and welfare outcomes observed among farms [71]. It is advisable to have health plans including vaccinations and practices to monitor and control ecto and endoparasites adjusted to local conditions and to the diseases of greater incidence, and biosecurity protocols [23,30,31]. Appropriate cleaning and disinfection of shelters and huts between batches of pigs is essential for the control of *Oesophagostomum* spp. and *Hyostrongylus* spp. [30]. Pigs should be handled firmly and calmly to avoid unnecessary pain or stress [31]. It is essential to maintain high standards of hygiene, to use the correct equipment for each intervention, and to properly sterilize syringes, needles, and scalpels [23]. Under certain circumstances, it would be necessary to implement painless and instantaneous euthanasia practices.

Supplementation with Herbal Compounds and Extracts

Some herbals have antioxidative, antimicrobial, analgesic, calming, and sedative properties that could be used to enhance gut health, increase nutrient absorption, improve feed intake and digestibility, minimize heat stress, and reduce pain and stress in pigs; thereby, improving their welfare. It has been suggested that *Aloysia citriodora* and *Stevia rebaudiana* can be used to decrease post-weaning stress and diarrhea in piglets [226,227]. The sedative and relaxing properties of *Valeriana officinalis* and *Passiflora incarnata* were tested as a stress-reducing strategy in finishing pigs. Lower negative social interactions, lesser body lesions, and an increase in body weight were observed in pigs supplemented with the herbal compounds [228]. An herbal mixture containing *Scutellaria baicalensis* and *Lonicera japonica* was added to diets of heat-stressed lactating sows; the sows supplemented with the herbal mixture showed higher feed intake, better dry matter digestibility, reduced backfat loss, and decreased cortisol levels. At weaning, their piglets presented greater weight and a lower diarrhea prevalence [229]. Similarly, giving sows 6 g/day caffeine mixed with the feed three days before farrowing increased gestation length (116.6 ± 0.3 vs. 115.6 ± 0.3 days), reduced the number of sows that delivered stillborn piglets (43.3% vs. 20.6%), and the piglets showed higher rectal temperature measured three hours after birth (38.0 ± 0.2 °C vs. 37.6 ± 0.2 °C) [230].

3.7. Housing and Handling Facilities

To protect pigs from extreme environmental conditions, adequate housing, shade, and alternatives for thermoregulation should be provided. Designing appropriate housing and handling facilities can prevent causing injuries and pain to the animals [137], protect against aggressive interactions with other animals, facilitate access to resources by subordinate animals, and provide safety to caretakers [19,25,31,33,174]. The preference of laying down inside the shelter at night is related to the feeling of protection and not to the feeling of cold. Even the youngest preferred to stay outside with temperatures up to 5 °C. [35]. In pasture pig production systems, individual or collective shelters and huts are portable, favoring the use of new ground for each batch of pigs. Corrugated iron arcs or wooden sheds, insulated or not, are the most frequent type of accommodation [231]. Housing for pasture pig systems should be adapted to animal growth stage, climate, availability of local materials, and labor costs. Shelters should have sufficient space per animals, proper orientation, appropriate construction materials, and good insulation to prevent injuries and illness and threats to animal welfare. Appropriate access to shelters for animals during different weather conditions, and for caretakers for operations of restrain and capture and cleaning, are necessary to ensure welfare of animals in grazing systems [127]. Moreover, shelters should be heavy enough or be anchored to the ground to prevent pigs or strong winds from overturning them.

The physiological needs of the sows in terms of space and substrate and the piglets' needs for protection against crushing and thermoregulation, and the economic performance of the systems should be considered during the design of a sustainable farrowing and lactation environments [159,160]. In pasture-based systems, the assistance to the sows during prolonged farrowing is difficult and the design of farrowing huts should consider features that allow birth supervision and assistance as well as piglets processing [232]. Farrowing–lactation huts should include a creep area and protection features for the piglets (sloped walls, rails, and raised bars), provision of dry absorbent bedding (10–15 cm) to ensure ventilation and avoid drafts, and may include curtains made with plastic strips at the entrances, which can help reduce pre-weaning mortality [31,233]. However, Vieuille et al. suggest caution when using bottom anti-crushing bars since contradictory results on piglet mortality among farms using them has been observed [23,234]. Additionally, farrowing huts can be furnished with barriers (fenders) that prevent piglets from leaving; thus, decreasing possibilities to become prey, but allowing sows to leave and enter at will [161,235]. It is desirable that farrowing huts maintain pleasant temperatures so that sows are motivated to return to them and nurse the piglets. Placing the huts in tree-sheltered areas or mounting a shade structure over huts and shelters can serve this purpose.

Appropriate shelters should consider proper ventilation, insulation, color of ceilings, reflectivity, inclination, and orientation, to ensure proper heat gain or loss of shelters in grazing systems. Shelters should be constructed using insulating material, and with the exterior painted white to reduce the impact of radiant energy [20,22,31,236]. Additionally, insulating the shelter roofs and the use of bedding during summer and winter are necessary to improve pig comfort [31,45]. Temperatures between insulated and uninsulated of farrowing huts were not different during winter months [235]; however, during summer uninsulated huts had higher temperatures and mortality rates in the first 24 h after farrowing than insulated huts. Furthermore, temperatures in uninsulated huts surpassed 25 °C during 5 h per day, which could prevent the sows entering the hut and nurse the piglets. [237]. In Denmark, individual insulated "A frame" farrowing huts furnished with bedding (straw) provided a microclimate able to prevent piglet hypothermia during winter. Nevertheless, during summer the number of stillborn was considered an indicator of heat stress in sows, which increased when hut temperature exceeds 27 °C [238].

During the winter months, air drafts should be avoided in the shelters [31]. It is beneficial to protect entrances, orienting them perpendicularly to the prevailing winds, and to provide bedding [31,33]. This is central to animal welfare, especially in farrowing huts where bedding can fulfill different functions such as nesting material, as a mattress that moderate sow changes of position; thus, reducing the risk of piglets being crushed, and establishing a microclimate that helps newborn piglets [12]. The use of plastic (PVC) strips-curtains on the doors can help minimize the possibility of the bed material getting wet through rain or snow seepage [31]. If soil around huts and shelters become very wet and muddy, they should be relocated.

Pasture area should guarantee the necessary water supply for the whole herd for one day [231]. During the hottest time of the year, periodic monitoring of the condition of distribution pipes that could be broken by the pigs is necessary to ensure appropriate water supply. It is also desirable to provide water to the piglets within the fender, outside the farrowing hut to avoid dehydration [44]. Heat stress from pasture pigs was alleviated when foggers were used. [20]. Extreme temperatures, both high and low, can affect the water supply systems. In summer, high temperatures heat pipes and drinking fountains; thus, limit water consumption, whereas in winter, pipes and drinking fountains are at risk of freezing. Burying pipes in the subsoil and placing the drinking fountains in the shade help to minimize these negative impacts.

Shade, preferably from natural vegetation, helps reduce the influence of solar radiation and high temperatures on animals and can alleviate thermal stress [20,30,49]. All animals in the group should have simultaneous access to shaded areas. Evaluations of the effect of including trees in pasture systems for pigs have been carried out in Europe. Sows that had access to trees (*Populus* spp.) spent more time outside the shelter compared to those managed in pastures without access to trees [236]. The sows at rest under the trees had a lower respiratory rate (30 vs. 45 breaths per min, respectively) [152]. The trees also act as windbreaks, reducing the sensation of cold [31].

4. Conclusions

Challenges to animal welfare can be found in most pig production systems. Pasture pig production systems pose specific challenges to animal welfare that are inherent to the nature of these systems, in which producers have little room to make improvements. However, these systems present other challenges that could be reduced with a carefully designed system, by adopting appropriate management strategies and by avoiding management practices that are likely to negatively affect animal wellbeing.

The use of animals that are adapted to pasture conditions contributes to improving animal welfare. Among the desirable characteristics that pigs raised under these systems should exhibit are adaptation to extreme temperatures, resistance to diseases, docility, maternal ability, and foraging and grazing aptitude. The design of the production system affects animal wellbeing, the working environment, and the potential environmental impact.

The welfare of pigs managed in pasture production systems may be challenged by the following factors:

- Exposure to extreme temperatures.
- Potential contact with wildlife and pathogens, especially parasites.
- Vulnerability to predators.
- Risk of malnutrition.
- Pre-weaning piglets' mortality.
- Complexity of the processes for monitoring, capturing, and treating sick animals, and for cleaning and disinfection of facilities and equipment.

Key factors to achieve adequate animal welfare include management skills and animal caretaker attitudes; hence, efforts should be made to provide workers and staff with appropriate training and motivation. Conversely, producers and operators can gradually minimize fear and anguish among animals by carefully supervising and finding solutions to issues that often arise, for instance, during feeding, grouping, mixing, and handling of animals.

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