Chapter

Immunocastration as Welfare Improvement in Outdoor Pig Production Systems

Sofia Botelho-Fontela, Gustavo Paixão, Rita Payan-Carreira and Alexandra Esteves

Abstract

Renowned for their high-quality meat from autochthonous breeds like the Iberian and Bísaro pigs, extensive pig farms prioritize animals' welfare as a crucial factor in maintaining meat quality. In these systems, pig welfare results from the importance of providing abundant space, allowing for the full expression of the species' behavior, and proper care. Immunocastration is a tool that might positively contribute to enhancing pig welfare and also provide a practical solution for managing male pig reproduction in extensive production systems. Immunocastration eliminates the need for surgical castration, such as avoiding the need for pain control, reducing potential post-surgical complications, and mitigating stress-related issues. Immunocastrated pigs exhibit improved behavior and feed efficiency. The desirable meat quality attributes of entire males are kept, while avoiding the boar taint issues, enhancing consumer acceptance and marketability. Through the application of immunocastration, extensive pig producers can achieve improved production efficiency and profitability while simultaneously addressing animal welfare concerns and meeting consumer preferences. In addition, immunocastration helps minimize the environmental impact of pig farming by decreasing nutrient runoff and waste pollution, promoting sustainable and ethical farming practices. This chapter intends to discuss the contribution of immunocastration to welfare improvement in non-industrial long-cycle extensive pig systems.

Keywords: boar taint, Improvac®, long production cycles, non-industrial systems, non-surgical castration, outdoor systems, pig wellbeing

1. Introduction

In the European Union, approximately 81 million piglets were surgically castrated in 2020, which represents approximately 31.5% of the total of pigs slaughtered that year [1]. This practice is usually performed without anesthesia or analgesia up to the age of 7 days [2], raising ethical concerns regarding pain and animal welfare [2–4]. The primary reason for this practice is to prevent boar taint [2, 3, 5–7], an unpleasant odor that affects consumer preference, and to prevent the increased aggressiveness and

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mounting behavior characteristic of non-castrated males [2]. Several options have been studied, but three main alternatives are being considered. The first alternative is surgical castration associated with anesthesia and pain control, which reduces animal suffering but adds cost and complexity to the process. Another could be raising only non-castrated males, which excludes the castration procedure but requires boar taint detection at slaughterhouses, raising potential economic concerns. And lastly, immunocastration, a vaccine against boar taint faces concerns about effectiveness, safety, and consumer perception.

A stepwise process marked the decision-making progression of banning surgical castration. In the ′70s–′80s, Denmark decided to raise only entire males and stop surgical castration for economic reasons. Boars have higher feed efficiency and deposit less fat, which confers to them a higher value than surgically castrated males. After Denmark successfully ended the practice of castrating pigs without significant setbacks, other countries, such as Norway and Switzerland, concerned about animal welfare began to pressure their governments to follow suit. Consumer awareness and preferences played a crucial role in influencing the industry. That was also the case in The Netherlands, as supermarkets stopped buying pork from pigs castrated without pain relief due to consumer pressure.

In 2010, a coalition of 33 stakeholders in the pork supply chain—including researchers, veterinarians, and animal welfare NGOs—came together to sign a voluntary agreement known as the "European Declaration on Alternatives to Surgical Castration of Pigs" [8]. They aimed to abolish the practice of surgically castrating pigs without pain relief by 2012 and then gradually phase out surgical castration of pigs by 2018 across all EU member states.

Despite scientific advancements and public pressure, we are now presented with a stalemate regarding the end of surgical castration without anesthesia and pain relief. While eight countries in the EU have already banned the practice, they disagree on the ideal alternative, hindering a unified EU approach. The different stakeholders have diverse motivations. Northern European countries like Denmark and Netherlands, major pork exporters, desire a harmonized solution for easier trade. Sweden prioritizes animal welfare but is less active in pushing an agreement. Southern European countries, like Spain and Portugal, have a tradition of raising uncastrated pigs, which are usually slaughtered before puberty, but lack commitment to banning surgical castration. To ban this procedure, the focus should become on allowing individual countries or regions to select the most fitting substitute dependent on their market and priorities. Further research and education are important to discover alternative techniques and promote their adoption.

The pressure from consumers affected not only the issue of surgical castration but also the methods used in pig rearing. As consumers started becoming more aware of animal welfare, including pain management and the absence of suffering, there was a growth in media protests highlighting their disapproval of the current dominant production system. Thus, conventional production in confined spaces with slatted floors is becoming increasingly unacceptable [9]. Surveys conducted worldwide confirm the societal shift toward the preference for free-range animals with unrestricted movement. This trend has been observed in countries such as Brazil [10], the United States [11], Canada [12], and Europe [13], where citizens are indicating their inclination toward animals that are free to roam.

The welfare of production animals is a strong concern for consumers and a major issue in pig industrial production systems. Enrichment materials can be given to pigs even in enclosed spaces to encourage natural behaviors and improve animal welfare without altering the housing structure [14]. However, alternative methods offering pigs environments where they can express their natural behaviors are becoming increasingly popular [15].

The purpose of this work is to discuss immunocastration as a means to improve animal welfare in traditional outdoor pig production systems.

2. Alternative systems for pig production

2.1 Sustainable livestock farming

A sustainable livestock farming system should have a neutral or positive impact on the environment, be compatible with the presence of local wildlife, and promote the recovery of higher levels of biodiversity. Moreover, it must ensure the welfare of the animals, prioritize the well-being of the local community, and be economically profitable [16]. Current systems for livestock production do not meet these requirements, sustaining the search for new production systems. Consumers demand that governments and industries ensure safe, nutritious food, abide by environmental and animal welfare standards, and adapt to climate changes, while increasing efficiency and productivity [16]. A great number of consumers also prefer animal products that not only come from natural conditions but also use traditional production methods [17].

Alternative systems, such as free-range/extensive or litter-based ones, can coexist alongside conventional systems. The term "outdoor pig production" refers to a method of raising pigs that involves providing them with access to the outdoors and allowing them to interact with the ground and vegetation. This practice has gained popularity in various regions of Europe, South Africa, and North America [18], leading to its rapid expansion. Whether the pigs roam freely outdoors all year round or have limited access to an outdoor yard open to the barn, it is a highly beneficial practice for the pig, as it provides greater space and environmental complexity [19], as well as foraging opportunities and a more diverse diet [20, 21]. These alternative production systems are often associated with local breeds, which are considerably different from highly productive commercial breeds, especially in terms of productivity and carcass and meat quality [19, 22], as well as in the length of the production cycle. Increased use of extensive production methods can enhance animal welfare and is therefore incorporated in most welfare-label pig production systems, such as organic and free-range systems [19]. These local, autochthonous breeds are usually more robust regarding weather conditions and more resilient to parasites and diseases than their commercial counterparts [22, 23]. This is one of the main reasons why they are largely used across Europe in these specific production systems [24].

2.2 Autochthonous breeds: a potential solution

Autochthonous breeds display significant differences in phenotypic and genetic traits, as well as production performance, mainly due to human activities, through selective breeding, adaptations to local climate, and mutations [25–27]. These breeds have been selected for inclusion in programs aimed at protecting genetic resources [28]. Their goal is to ensure the breeds' sustainability by maintaining their genetic uniqueness, stabilizing the population size, and preserving both the breed's phenotypic traits and their valuable performance traits [28].

Although raised in low numbers compared to commercial breeds, native pig breeds are better adapted to local conditions; they represent an opportunity for developing sustainable pork value chains [29]. Specific production systems used in these breeds usually align better with societal expectations of animal welfare, environmental adaptation, and food quality [30]. Not only that, but the products provided, especially the traditional meat products, represent cultural and gastronomical heritage with an excellent reputation among consumers due to their distinctive quality attributes, as well as an emotional connection, which cannot be replicated with pigs from conventional intensive systems [31]. Autochthonous breeds have slower growth rates than commercial breeds [32, 33] and very heterogeneous results. Brossard et al. [34] studied nine different European autochthonous breeds and found that the mean daily protein deposition ranged between 41 and 116 g/d. A major advantage of these breeds is their more efficient digestion of fiber due to the richness of their cellulolytic and hemicellulolytic flora [35]. This makes them incredibly adapted to extensive production systems and capable of being reared in marginal land with poor feed resources, characteristic of permanent grassland [35, 36].

Furthermore, native pig breeds usually integrate production chains of added-value products, such as certified traditional meat products with Protected Designation of Origin (PDO) and/or Protected Geographical Indication(PGI) [37]. These products request slaughter at older ages, along with longer fattening free-ranging cycles for which animals should not be able to express reproductive activity (as a source of male-to-male aggression or female pregnancy before slaughter) as it can disturb the expected performance of animals. In this scenario, immunocastration appears to be an interesting strategy.

3. Immunocastration: mechanism and applications

3.1 Principles of immunocastration

Immunocastration, also known as immunological castration or vaccine-induced castration, relies on the temporary neutralization of the hypothalamic–pituitary-gonadal axis through the antibodies generated by the immune system. Consequently, the gonadal activity is suppressed, as well as the boar-taint-related compounds, namely androstenone and skatole [38, 39].

The vaccine available in Europe—the Improvac® (Zoetis Animal Health – Global Animal Health Company)—contains a synthetic copy of Gonadotropin-Releasing Hormone (GnRH) coupled to an immunogenic protein (a diphtheria toxoid), combined with a synthetic aqueous adjuvant (DEAE-Dextran) to promote the necessary immune response [40]. The diphtheria toxoid, a foreign molecule to the organism, will induce an immune reaction driving the formation of antibodies against GnRH. Once a sufficient level of antibodies is produced to destroy the endogenous hormone, it will originate a suppression of the hypothalamic pituitary gonadal axis [41] and ultimately will suppress the secretion of sex steroid by the gonads [42]. The onset of immunity happens when anti-GnRH antibody production is induced, which normally happens 1 week after the second vaccination. A temporary decrease in the production of gonadotropins and sex steroids will lead to inhibition of sexual behavior and gametogenesis will be suspended. Licensed for use in boars since 2009, this vaccine has been recently authorized in Europe to also be employed in sows, for sexual behavior control (standing estrus) [40].

The standard immunization protocol involves two subcutaneous injections of the vaccine at least 4 weeks apart, with the second immunization administered four to 6 weeks before slaughter [43]; this time interval ensures effective boar taint reduction. Reduction of aggressive and sexual (mounting or standing estrus) behaviors should be expected one or 2 weeks post second vaccination [40]. Nevertheless, the need for a third administration, at least 4 weeks after the second in older, culled intact boars has been recommended. Since the vaccination is reversible [44], the standard protocol can be adapted into an early [43, 45, 46] or long-term [47–50] protocol to accommodate the particularities of each pork production system and avoid recurrences. Similar to other vaccines, the immunocastration does not have a withdrawal period [40], due to the lack of residues in the meat. Nevertheless, like with other vaccines, the application of the product must comply with specific recordings at the farm designed to guarantee the trackability of meat and meat products safely from the farm to the consumer.

3.2 Effectiveness of immunocastration in reducing boar taint

The boar taint is an intensive off-flavor aroma commonly associated with the accumulation in the fat of at least one of the two compounds: skatole, a byproduct of the amino acid tryptophan produced by bacteria in the hindgut of pigs, subject to a multifactorial influence [51]; or androstenone, a testicular steroid with a urine-like odor [52, 53].

Several studies have tested and proved the immunocastration efficacy in reducing boar taint [54–58], which is now generally agreed upon [42]. Its efficacy in reducing boar taint compounds has also been proven in alternative production systems, using local breeds [59–61], but often requires an extension or modification of the standard protocol [47, 62]. While androstenone reduction is easily explainable because of the suppression of the testicular function, the influence of immunocastration on skatole levels is not yet fully understood. It is believed that immunocastration decreases skatole formation within the intestine and accelerates skatole degradation metabolism in the liver by increasing skatole-metabolizing enzymes CYP2E1, CYP2A, CYP2C49, and CYB5A expressions [63]. Reducing dietary energy concentration lowers intestinal skatole production [64] that can be useful in finishing immunocastrated pigs which have increased feed intake.

Nonetheless, there is some controversy about the full efficacy of the standard immunocastration protocol. Some authors report the random occurrence of non-responding animals [65, 66]. Although the percentage of non-responders is very low, considering that vaccination was performed properly, chances of injection failure are possible and likely to happen in field conditions [52].

3.3 Potential side effects and limitations

One of the main concerns of immunocastration is the safety of operators [67]. GnRH is found in all mammals and in humans as well. In principle, a repeated auto-injection by the operator would have the same results as in the target species. This can be virtually ruled out by using an injector gun with a needle guard.

A possible side effect in pigs includes moderate injection site swellings, most often classified as mild reactions [65]. These events do not affect the vaccine efficacy but can result in slaughterhouse partial part condemnation.

As mentioned earlier, immunocastration is reversible. From 10 weeks after the last injection, a return of testicular function can start presenting itself [68] with subsequent gonadal regrowth [47]. This can be considered a limitation, as revaccination is required in order to maintain animals castrated.

Consequently, this requires an adaptation to the original immunocastration scheme. The new approach can be considered a major limitation for farmers who operate small to medium-scale alternative systems, using non-industrial breeds [62]. Several studies have already been made toward this goal [47, 48, 59, 62, 69–77] but no consensus was reached. Internal factors, such as individual variations and age at administration, can affect its efficacy. So, it is crucial to identify the most suitable vaccination protocol for alternative production systems, considering the specifics of the pig breed, the length of the productive cycle, age at slaughter, and whether the animal is a young or culled mature boar or sow. Each production system has its own individual traits which should be taken into consideration when designing the vaccination schemes.

4. Welfare benefits of immunocastration

4.1 Ethical considerations and animal welfare standards

Animal welfare has been a major concern for the European Commission in the last decades, especially in the pork production industry. Surgical castration of male pigs has been targeted as a priority, and the European Commission proposed to end all surgical castrations by 2018 [8]. Six years have passed, and the main objective is far from met [78]. According to the last published enquiry, 75% of male pigs are still surgically castrated in the European Union [79]. In agreement with the EU legislation [8], surgical castration of pigs without anesthesia or analgesia in pigs is allowed up to 7 days of age, and most procedures in industrialized systems are performed this way. Germany and France came forward and from January 2021 and 2022, respectively, have restricted surgical castration further, demanding, among other aspects, effective anesthesia before surgical castration and mandatory training for staff [80–82].

Outside Europe, immunocastration has been largely used in the last two decades, particularly in Australia and New Zealand, and has been recently developed in South America [52]. In the United States of America, surgical castration is used on nearly all animals [83] and is normally performed without analgesia or anesthesia up to 14 days of age, as recommended by the American Veterinary Medical Association (AVMA) [84].

4.2 Mitigation of surgical castration-related effects

Scaling animal pain is one of the more challenging obstacles to animal science. A possible explanation is that the magnitude and pain-associated behaviors may differ between species, breeds, and between individuals making the assessment subject to bias [6]. Regarding pigs, even farmers and veterinarians have difficulties in reliably recognizing pain [85]. Still, it is currently recognized that surgical castration procedures are associated with pain, stress, and risk of infection [2, 46, 86–88]. In contrast, some authors hypothesized that animals will not recall that experience at such a young age, such as humans do not recall many experiences as babies [89]. Additionally, it has been suggested that pigs are not as sensitive to pain as humans are [85]. No consensus was reached on those topics even though recent studies showed that pain-related behaviors and physiological stress indicators are unaltered with age [90, 91]. Concerns about pain related to the surgical gonadectomy dictate consumer choices and impact consumers acceptance of meat from neutered animals [92–94], despite that in most cases they do not have enough information to make a decision based on knowledge [95].

Surgical castration of male piglets is a common management practice in pig farms, usually performed by farm workers. The piglets are restrained, normally by suspending them upside down, by their hind limbs, laid across a smooth rail, or in a tilted castration table or through. The skin of the scrotum is cut, the testicle is exteriorized, and then, often is steadily pulled from the scrotum until the spermatic cord is torn [96, 97]. Most often a two-incision technique is used, so the procedure is repeated in the remaining scrotal testicle. Discomfort with increased vocalization and body temperature (fever) is common in the days following the procedure, which is reflected in a decreased growth rate [2, 7]. Most common post-surgical complications of surgical castration are infection and abscess formation [98]. Illness, poor performance, or death can occur within the peri-operative period, negatively impacting the suckling period. Morales et al. [99] showed that surgical castration had increased pre-weaning mortality and negatively affected body weight at weaning, in the heaviest piglets.

Contrastingly, the immunocastration technique involves two, in some cases three subcutaneous injections of a small volume (2 mL). A limited amount of transient pain due to the needle insertion might happen [86]. However, from an ethical point of view, it is considered negligible. The procedure does not require ethical approval [100]. In industrialized full-indoor industrialized systems, the vaccination is often performed without any kind of physical restrain, keeping the animals in their environment undisturbed. In outdoor systems, however, the injections may cause some practical difficulties, as they usually require restraining the animals which may disturb the pigs' normal daily routine. Still, the immunocastration can be categorized as an animal-friendly method, similar to any other routine vaccination procedure [101].

In countries and systems where animals are kept only until shortly after they reach sexual maturity, the standard protocol with two injections is enough to avoid any dominance-related behaviors. However, in systems where animals are slaughtered at older ages, additional vaccination boosters, totalizing three or even four injections, might be needed to prolong the suppressive effects on the gonadal activity. These long-term, earlier protocols were tested in some experiments and successfully reduced secretion of sex steroid hormones and controlled boar taint [45, 46], reducing the chances of aggressive sexually driven behaviors.

4.3 Improvement of behavior and social interactions

Castration in pigs is campaigned because it modifies behaviors favoring the coexistence between animals from the same group, while also preventing unwanted breeding and the development of boar taint compound [102, 103]. After the second vaccination, most pigs will behave like surgically castrated animals. Thus, undesirable aggressive and mounting behaviors typical of the intact males are significantly reduced after the second immunization [52, 104, 105], resulting in less skin lesions observed at slaughterhouse [106]. These suppressive effects might last up to 16 or 22 weeks after the second vaccination [107].

Penile injuries in entire male pigs have been largely discussed as a relevant welfare problem in pork production. A recent study [108] indicates high incidence of this phenomenon in boars in contrast with barrows, whereas this issue is not detected. Contrary to surgical castration, immunocastration does not eliminate penile injuries, but significantly reduces them and their severity [109, 110].

5. Impact of immunocastration on alternative farming

5.1 Challenges of outdoor access

As already mentioned, alternative farming systems are often characterized by the animal's outdoor access. Most autochthonous breeds in the Iberian region are raised in extensive systems and free-range conditions, where they are mostly kept in outdoor pens, permaculture pastures, or even sparsely forested grasslands [111]. In those systems, both males and females are slaughtered at 14–16 months old [111]. This implies that unintended pregnancies may occur due to mating with domestic or wild boars [77, 112]. As wild boars search for females in heat in the rutting season [113], the absence of female heat can be a factor in diminishing disease transmission, such as the African Swine Fever.

To avoid this problem, not only males but also females are gonadectomized at younger ages [77, 114], increasing the risk of infection and subsequently welfare issues [76]. Immunocastration can prevent estrus and ovulation in females [53, 72, 115], presenting itself as a better solution for these systems than surgical castration welfare-wise.

5.2 Balancing welfare and performance

One of the issues of raising entire males to the typical ages of autochthonous breeds is the sexual and aggressive behavior. Prior to the second inoculation, pigs that have undergone immunocastration may exhibit behaviors that are typical of entire males and can be classified as such [116]. As mentioned before, these aggressive and mounting occurrences result in a decrease in animal welfare, evident in the higher number of skin lesions presented in these animals [106, 116]. After the second inoculation, the incidence of skin lesions disappears [117] and less aggressive behavior is observed [106, 118], significantly improving their animal welfare [119].

It has been reported that the best productive parameters such as average daily weight gain (DWG) and feed conversion ratio (FCR) are better in immunocastrated pigs than in the surgically castrated [61]. This phenomenon becomes more pronounced in the latter stages of rearing and fattening (>80 kg BW), when the immunocastration is performed in older, post-pubertal animals [109, 120].

On that regard, the immunocastrated pigs behave similarly to the entire males. After the second injection, average daily feed intake (ADFI) increases sharply, thus resulting in faster and more efficient growth [121]. In sum, immunocastration can be considered as an intermediate between surgically castrated and entire males in overall performance. Thus, for the fattening period, immunocastration is more efficient than surgical castration [42, 107]. Recently, Poulsen Nautrup et al. [122] in a meta-analysis confirmed that immunocastrated pigs have higher DWG and lower FCR compared to those surgically castrated.

Considering productive performances, immunocastrated pigs are able to use the full growth potential of entire males, while also benefiting from the metabolism of castrated animals [65]. Therefore, presenting better performance when compared to surgically castrated males [42, 123]. Heavier carcasses, higher percentages of lean meat, and lower fat thickness are the defining characteristics of this improvement [42, 61, 122].

As the effect of Improvac® is reported as "reversible", there was a major concern from the farmers of these breeds as to what the correct immunocastration scheme ought to be used [62]. Several studies have already been made toward this goal

[47, 48, 59, 62, 69–77] but no consensus was reached. Each production system has its own individual traits which should be taken into consideration when designing the vaccination schemes.

6. Conclusion

Surgical castration is frowned upon by consumers due to the pain and stress inflicted on the animals. Several alternatives have been procured, but not many can be applied to the production systems characteristic of autochthonous breeds. Raising entire males and females up to the normal slaughter age, far after their sexual maturity, often results in several issues, such as aggressive behavior and possible unwanted pregnancies. As consumers prioritize animal welfare, immunocastration presents itself as a viable solution. Besides the obvious welfare and well-being advantages, immunocastrated pigs also have superior production performance when compared to surgically castrated males, a big economic advantage for their breeders.

Appropriate protocols should be designed for each breed and production system to determine the most effective protocol, while also harmonizing the regulations for wider adoption of this method. Consumer education should also be a priority, as their awareness and support are crucial for promoting immunocastration acceptance.

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Conflict of interest

The authors declare no conflict of interest.

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References

[1] van Ferneij JP. The pig castration situation in the European Union – Articles – pig333, pig to pork community. 2022. Available from: https://www.pig333.com/articles/the-pig-castration-situation-in-the-european-union_18100/ [Accessed: 20 March 2024]

[2] Von Borell E, Baumgartner J, Giersing M, Jäggin N, Prunier A, Tuyttens FAM, et al. Animal welfare implications of surgical castration and its alternatives in pigs. Animal. 2009;**3**(11):1488-1496

[3] Weiler U, Font-I-Furnols M, Tomasevič I, Bonneau M. Alternatives to piglet castration: From issues to solutions. Animals. 2021;**11**(4):1-6

[4] Lin-Schilstra L, Ingenbleek PTM. A complex ball game: Piglet castration as a dynamic and complex social issue in the EU. Journal of Agricultural and Environmental Ethics. 2022;**35**(3)

[5] Neary JM, Jacobs L, Clark-deener S, Neary JM. Surgical castration in piglets: Its impacts on pain and affectice states [Doctoral dissertation]. Virginia Tech; 2022

[6] Miller R, Grott A, Patzkéwitsch D, Döring D, Abendschön N, Deffner P, et al. Behavior of piglets in an observation arena before and after surgical castration with local anesthesia. Animals. 2023;**13**(3):1-13

[7] Leidig MS, Hertrampf B, Failing K, Schumann A, Reiner G. Pain and discomfort in male piglets during surgical castration with and without local anaesthesia as determined by vocalisation and defence behaviour. Applied Animal Behaviour Science. 2009;**116**(2-4):174-178

[8] European Commission. European Declaration on alternatives to surgical castration of pigs. 2010. Available from: https://ec.europa.eu/food/sites/food/files/animals/docs/aw_prac_farm_pigs_castalt_declaration_en.pdf [Accessed: 20 March 2024]

[9] Kanis E, Groen ABF, De Greef KH. Societal concerns about pork and pork production and their relationships to the production system. Journal of Agricultural and Environmental Ethics. 2003;**16**:137-162

[10] Yunes MC, Von Keyserlingk MAG, Hötzel MJ. Brazilian citizens' opinions and attitudes about farm animal production systems. Animals. 2017;**10**:75

[11] Sato P, Hötzel MJ, Von Keyserlingk MAG. American citizens' views of an ideal pig farm. Animals. 2017;**7**:64

[12] Ryan EB, Fraser D, Weary DM. Public attitudes to housing systems for Pregnant Pigs. PLoS One. 2015;**10**:e0141878

[13] Krystallis A, de Barcellos MD, Kügler JO, Verbeke W, Grunert KG. Attitudes of European citizens towards pig production systems. Livestock Science. 2009;**126**:46-56

[14] Godyń D, Nowicki J, Herbut P. Effects of environmental enrichment on pig welfare—A review. Animals. 2019;**9**:383

[15] Guy JH, Edwards S. Alternative production systems. In: Livestock Production and Society. Wageningen, The Netherlands: Wageningen Academic Publishers; 2006. pp. 273-286

[16] Alonso ME, González-Montaña JR, Lomillos JM. Consumers' concerns and

perceptions of farm animal welfare. Animals. 2020;**10**:385

[17] Poklukar K, Čandek-Potokar M, Batorek Lukač N, Škrlep M. Biochemical and gene expression differences associated with higher fat deposition in Krškopolje pigs in comparison with lean hybrid pigs. Livestock Science. 2023;**272**:105247

[18] Honeyman MS. Extensive bedded indoor and outdoor pig production systems in USA: Current trends and effects on animal care and product quality. Livestock Production Science. 2005;**94**:15-24

[19] Früh B, Bochicchio D, Edwards S, Hegelund L, Leeb C, Sundrum A, et al. Description of organic pig production in Europe. Organic Agriculture. 2014;**4**:83-92

[20] Rodríguez-Estévez V, García A, Peña F, Gómez AG. Foraging of Iberian fattening pigs grazing natural pasture in the dehesa. Livestock Science. 2009;**120**:135-143

[21] Jakobsen M, Kongsted AG, Hermansen JE. Foraging behaviour, nutrient intake from pasture and performance of free-range growing pigs in relation to feed CP level in two organic cropping systems. Animal. 2015;**9**:2006-2016

[22] Nevrkla P, Kapelański W, Václavková E, Hadaš Z, Cebulska A, Horký P. Meat quality and fatty acid profile of pork and backfat from an indigenous breed and a commercial hybrid of pigs. Annals of Animal Science. 2017;**17**:1215-1227

[23] Blacksell SD, Khounsy S, Van AD, Gleeson LJ, Westbury HA. Comparative susceptibility of indigenous and improved pig breeds to classical swine fever virus infection: Practical and epidemiological implications in a subsistence-based, developing country setting. Tropical Animal Health and Production. 2006;**38**:467-474

[24] Delsart M, Pol F, Dufour B, Rose N, Fablet C. Pig farming in alternative systems: Strengths and challenges in terms of animal welfare, biosecurity, animal health and pork safety. Agriculture. 2020;**10**:1-34

[25] Zorc M, Škorput D, Gvozdanović K, Margeta P, Karolyi D, Luković Z, et al. Genetic diversity and population structure of six autochthonous pig breeds from Croatia, Serbia, and Slovenia. Genetics, Selection, Evolution. 2022;**54**:30

[26] Sponenberg DP, Sponenberg DP, Beranger J, Martin AM. Conservation of rare and local breeds of livestock. Revue Scientifique Et Technique De L Office International Des Epizooties. 2018;**37**:259-267

[27] Groeneveld LF, Lenstra JA, Eding H, Toro MA, Scherf B, Pilling D, et al. Genetic diversity in farm animals – A review. Animal Genetics. 2010;**41**(Suppl. 1):6-31

[28] Kasprzyk A, Walenia A. Native pig breeds as a source of biodiversity—Breeding and economic aspects. Agriculture (Switzerland). 2023;**13**(8):1528

[29] Herrero M, Thornton PK, Gerber P, Reid RS. Livestock, livelihoods and the environment: Understanding the trade-offs. Current Opinion in Environment Sustainability. 2009;**1**(2):111-120

[30] Verbeke W, Pérez-Cueto FJA, de Barcellos MD, Krystallis A, Grunert KG. European citizen and consumer attitudes and preferences regarding beef and pork. Meat Science 2010;84(2):284-292.

[31] Bonneau M, Lebret B. Production systems and influence on eating quality of pork. Meat Science. 2010;**84**(2):293-300

[32] Pugliese C, Sirtori F. Quality of meat and meat products produced from southern European pig breeds. Meat Science. 2012;**90**(3):511-518

[33] Čandek-Potokar M, Fontanesi L, Lebret B, Gil JM, Ovilo C, Nieto R, et al. Introductory Chapter: Concept and Ambition of project TREASURE. In: European Local Pig Breeds – Diversity and Performance: A Study of Project TREASURE. London, United Kingdom; 2019. pp. 3-9. Available from: https://books.google.com/books/about/European_Local_Pig_Breeds_Diversity_and.html?hl=pt-PT&id=btT9DwAAQBAJ

[34] Brossard L, Nieto R, Charneca R, Araujo JP, Pugliese C, Radović Č, et al. Modelling nutritional requirements of growing pigs from local breeds using InraPorc. Animals. 2019;**9**(4):169. Available from: https://www.mdpi.com/2076-2615/9/4/169/htm

[35] Morales J, Gispert Martinell M, Hortós M, Pérez J, Suárez P, Piñeiro Noguera C. Evaluation of production performance and carcass quality characteristics of boars immunised against gonadotropinreleasing hormone (GnRH) compared with physically castrated male, entire male and female pigs. Spanish Journal of Agricultural Research. 2010;**8**(3):599-606. Available from: https://dialnet.unirioja.es/servlet/articulo?codigo=3277203&info=resumen&idioma=ENG

[36] Kristensen TN, Hoffmann AA, Pertoldi C, Stronen AV. What can livestock breeders learn from conservation genetics and vice versa? Frontier in Genetics. 2015;**5**(Feb):121860. Available from: https://www.frontiersin.org

[37] Čandek-Potokar M, Giusto Conti A, Cosola C, Fontanesi C, et al. Improving sustainability of local pig breeds using quality labels – case review and trademark development in project TREASURE. Archivos de zootecnia. 2018;**1**:235-238. Available from: https://dialnet.unirioja.es/servlet/articulo?codigo=6537168&info=resumen&idioma=ENG

[38] Aluwé M, Tuyttens FAM, Millet S. Field experience with surgical castration with anaesthesia, analgesia, immunocastration and production of entire male pigs: Performance, carcass traits and boar taint prevalence. Animal. 2015;**9**(3):500-508. Available from: https://www.cambridge.org/core/journals/animal/article/abs/field-experience-with-surgical-castration-with-anaesthesia-analgesia-immunocastration-and-production-of-entire-male-pigs-performance-carcass-traits-and-boar-taint-prevalence/4614ADF453235495F795FD49B31CED40

[39] Backus G, Ur W, Støier S, Bonneau M, Higuera M. First progress report from the European declaration on alternatives to surgical castration of pigs (16/12/2010) Report from the Expert Group on ending the surgical castration of pigs (2012-2014). 2014

[40] EMA. Improvac: EPAR – Product Information (EMEA/V/C/136). 2022

[41] Zamaratskaia G, Rydhmer L, Andersson HK, Chen G, Lowagie S, Andersson K, et al. Long-term effect of vaccination against gonadotropin-releasing hormone, using Improvac™, on hormonal profile and behaviour of male pigs. Animal Reproduction Science. 2008;**108**(1-2):37-48

[42] Batorek N, Čandek-Potokar M, Bonneau M, Van Milgen J. Meta-analysis of the effect of immunocastration on

production performance, reproductive organs and boar taint compounds in pigs. Animal. 2012;**6**(8):1330-1338. Available from: https://www.cambridge.org/core/journals/animal/article/abs/metaanalysis-of-the-effect-of-immunocastration-on-production-performance-reproductive-organs-and-boar-taint-compounds-in-pigs/9A76C7355E435AEE7A4-37F3B86076B75

[43] Werner D, Baldinger L, Bussemas R, Büttner S, Weißmann F, Ciulu M, et al. Early immunocastration of pigs: From farming to meat quality. Animals. 2021;**11**(2):298. Available from: https://www.mdpi.com/2076-2615/11/2/298/htm

[44] Lugar DW, Rhoads ML, Clark-Deener SG, Callahan SR, Revercomb AK, Prusa KJ, et al. Immunological castration temporarily reduces testis size and function without long-term effects on libido and sperm quality in boars. Animal. 2016;**11**(4):643-649. Available from: http://hdl.handle.net/10919/73920

[45] Sladek Z, Prudikova M, Knoll A, Kulich P, Steinhauserova I, Borilova G. Effect of early immunocastration on testicular histology in pigs. Veterinary Medicine (Praha). 2018;**63**(01):18-27

[46] Brunius C, Zamaratskaia G, Andersson K, Chen G, Norrby M, Madej A, et al. Early immunocastration of male pigs with Improvac® – Effect on boar taint, hormones and reproductive organs. Vaccine. 2011;**29**(51):9514-9520

[47] Paixão G, Fontela SB, Marques J, Esteves A, Charneca R, Payan-Carreira R. Long-term immunocastration protocols successfully reduce testicles' size in Bísaro Pigs. Animals. 2021;**11**(3):632. Available from: https://www.mdpi.com/2076-2615/11/3/632/htm

[48] Hernández-García FI, Duarte JL, Pérez MA, Raboso C, Del RAI, Izquierdo M. Successful long-term pre-pubertal immunocastration of purebred iberian gilts reared in extensive systems. Acta agriculturae Slovenica. 2013;**2013**(Supplement):123-126

[49] Gogić M, Radović Č, Čandek-Potokar M, Petrović M, Radojković D, Parunović N, et al. Effect of immunocastration on sex glands of male Mangulica (Swallow-bellied Mangalitsa) pigs. Revista Brasileira de Zootecnia. 2019;**48**:e20180286. Available from: https://www.scielo.br/j/rbz/a/s4k9ZTXwgGc8qtKZ5v7VK9B/?lang=en

[50] Einarsson S, Andersson K, Wallgren M, Lundström K, Rodriguez-Martinez H. Short- and long-term effects of immunization against gonadotropin-releasing hormone, using Improvac™, on sexual maturity, reproductive organs and sperm morphology in male pigs. Theriogenology. 2009;**71**(2):302-310

[51] Weiler U, Götz M, Schmidt A, Otto M, Müller S. Influence of sex and immunocastration on feed intake behavior, skatole and indole concentrations in adipose tissue of pigs. Animal. 2013;**7**(2):300-308

[52] Bonneau M, Weiler U. Pros and cons of alternatives to piglet castration: Welfare, boar taint, and other meat quality traits. Animals. 2019;**9**(11):884. Available from: https://www.mdpi.com/2076-2615/9/11/884/htm

[53] Botelho-Fontela S, Paixão G, Pereira-Pinto R, Vaz-Velho M, dos Pires M, Payan-Carreira R, et al. Effect of immunocastration on Culled Sows—A preliminary study on reproductive tract, carcass traits, and meat quality. Veterinary Sciences. 2023;**10**(10):600. Available from: https://www.mdpi.com/2306-7381/10/10/600/htm

[54] Font-i-Furnols M, Carabús A, Muñoz I, Čandek-Potokar M, Gispert M. Evolution of testes characteristics in entire and immunocastrated male pigs from 30 to 120 kg live weight as assessed by computed tomography with perspective on boar taint. Meat Science. 2016;**116**:8-15

[55] Kubale V, Batorek N, Škrlep M, Prunier A, Bonneau M, Fazarinc G, et al. Steroid hormones, boar taint compounds, and reproductive organs in pigs according to the delay between immunocastration and slaughter. Theriogenology. 2013;**79**(1):69-80

[56] Zamaratskaia G, Andersson HK, Chen G, Andersson K, Madej A, Lundström K. Effect of a gonadotropin-releasing hormone vaccine (Improvac™) on steroid hormones, boar taint compounds and performance in entire male pigs. Reproduction in Domestic Animals. 2008;**43**(3):351-359

[57] Škrlep M, Šegula B, Zajec M, Kastelic M, Košorok S, Fazarinc G, et al. Effect of Immunocastration (Improvac®) in fattening pigs I: Growth performance, reproductive organs and malodorous compounds. Slovenian Veterinary Research. 2010;**47**(2):57-64

[58] Škrlep M, Batorek N, Bonneau M, Prevolnik M, Kubale V, Čandek-Potokar M. Effect of immunocastration in group-housed commercial fattening pigs on reproductive organs, malodorous compounds, carcass and meat quality. Czech Journal of Animal Science. 2012;**57**(6):290-299

[59] Botelho-Fontela S, Paixão G, Pereira-Pinto R, Vaz-Velho M, Pires MA, Payan-Carreira R, et al. The effects of different immunocastration protocols on meat quality traits and boar taint compounds in male Bísaro pigs. Theriogenology. 2024;**214**:89-97

[60] Botelho-Fontela S, Ferreira S, Paixão G, Pereira-Pinto R, Vaz-Velho M, Dos M, et al. Seasonal variations on testicular morphology, boar taint, and meat quality traits in traditional outdoor pig farming. Animals. 2023;**14**(1):102. Available from: https://www.mdpi.com/2076-2615/14/1/102/htm

[61] Grela ER, Świątkiewicz M, Kowalczuk-Vasilev E, Florek M, Kosior-Korzecka U, Skałecki P. An attempt of implementation of immunocastration in swine production – Impact on meat physicochemical quality and boar taint compound concentration in the meat of two native pig breeds. Livestock Science. 2020;**232**:103905

[62] Pinna A, Schivazappa C, Virgili R, Parolari G. Effect of vaccination against gonadotropin-releasing hormone (GnRH) in heavy male pigs for Italian typical dry-cured ham production. Meat Science. 2015;**110**:153-159

[63] Han X, Zhou M, Cao X, Du X, Meng F, Bu G, et al. Mechanistic insight into the role of immunocastration on eliminating skatole in boars. Theriogenology. 2019;**131**:32-40

[64] Batorek-Lukač N, Čandek-Potokar M, Škrlep M, Kubale V, Labussière E. Effect of changes in dietary net energy concentration on growth performance, fat deposition, Skatole production, and intestinal morphology in Immunocastrated male pigs. Frontiers in Veterinary Science. 2021;**8**:789776

[65] Čandek-Potokar M, Škrlep M, Zamaratskaia G, Čandek-Potokar M, Škrlep M, Zamaratskaia G. Immunocastration as alternative to surgical castration in pigs. Theriogenology. 2017. Available from: https://www.intechopen.com/chapters/55006

[66] Zamaratskaia G, Rasmussen MK. Immunocastration of male pigs

– Situation today. Procedia Food Science. 2015;**5**:324-327

[67] von Borell E, Bonneau M, Holinger M, Prunier A, Stefanski V, Zöls S, et al. Welfare aspects of raising entire male pigs and immunocastrates. Animals. 2020;**10**(11):2140. Available from: https://www.mdpi.com/2076-2615/10/11/2140/htm

[68] Claus R, Rottner S, Rueckert C. Individual return to Leydig cell function after GnRH-immunization of boars. Vaccine. 2008;**26**(35):4571-4578

[69] Pérez-Ciria L, Miana-Mena FJ, López-Mendoza MC, Álvarez-Rodríguez J, Latorre MA. Influence of immunocastration and diet on meat and fat quality of heavy female and male pigs. Animals. 2021;**11**(12):3355

[70] Font-i-Furnols M, García-Gudiño J, Izquierdo M, Brun A, Gispert M, Blanco-Penedo I, et al. Non-destructive evaluation of carcass and ham traits and meat quality assessment applied to early and late immunocastrated Iberian pigs. Animal. 2021;**15**(4):100189

[71] Granados PP, Fernández-Fígares I, Seiquer I, Lara L. Performance, metabolic and meat quality implications of immunocastration in Iberian pigs. 2021. Available from: https://www.researchgate.net/publication/355197476

[72] Dalmau A, Velarde A, Rodríguez P, Pedernera C, Llonch P, Fàbrega E, et al. Use of an anti-GnRF vaccine to suppress estrus in crossbred Iberian female pigs. Theriogenology. 2015;**84**(3):342-347

[73] Izquierdo M, Pérez MA, Rosario AI, Rodriguez P, García-Gudiño J, Duarte JL, et al. The effect of immunocastration on carcass and meat cut yields in extensively reared Iberian gilts. Acta argiculturae Slovenica. 2013;**2013**(Supplement):151-154. Available from: https://www.researchgate.net/publication/301290362

[74] Seiquer I, Palma-Granados P, Haro A, Lara L, Lachica M, Fernández-Fígares I, et al. Meat quality traits in longissimus lumborum and gluteus medius muscles from immunocastrated and surgically castrated Iberian pigs. Meat Science. 2019;**150**:77-84

[75] Hernández García FI, Izquierdo Cebrián M, Rosario González AI del, Montero A, Pérez MA, García Gudiño J, et al. Adaptation of immunocastration treatment to montanera system for male Iberian pigs: Effects on reproductive organs and carcass traits. Archivos de zootecnia 20182018(1):97-100. Available from: https://dialnet.unirioja.es/servlet/articulo?codigo=6537179&info=resumen&idioma=ENG

[76] Serrano MP, Valencia DG, Fuentetaja A, Lázaro R, Mateos GG. Effect of castration on productive performance, carcass characteristics and meat quality of Iberian pig females reared under intensive management systems. Livestock Science. 2009;**123**(2-3):147-153

[77] Martinez-Macipe M, Rodríguez P, Izquierdo M, Gispert M, Manteca X, Mainau E, et al. Comparison of meat quality parameters in surgical castrated versus vaccinated against gonadotrophin-releasing factor male and female Iberian pigs reared in free-ranging conditions. Meat Science. 2016;**111**:116-121

[78] De Briyne N, Berg C, Blaha T, Temple D. Pig castration: Will the EU manage to ban pig castration by 2018? Porcine Health Management. 2016;**2**(1):1-11. Available from: https://link.springer.com/articles/10.1186/s40813-016-0046-x

[79] Backus G, Higuera M, Juul N, Nalon E, De Briyne N. Second Progress

Report 2015-2017 on the European Declaration on Alternatives to Surgical Castration of Pigs. Brussels, Belgium; 2018

[80] DGAL. Instruction technique DGAL/SDSBEA/2023-84 [Internet]. 2023. Available from: https://info.agriculture.gouv.fr/gedei/site/bo-agri/instruction-2023-84

[81] Xicluna P. Interdiction de la castration à vif des porcelets: accompagnement de sa mise en œuvre | Ministère de l'Agriculture et de la Souveraineté alimentaire [Internet]. 19 Nov 2021. Available from: https://agriculture.gouv.fr/interdiction-de-la-castration-vif-des-porcelets-accompagnement-de-sa-mise-en-oeuvre

[82] BMEL – Tierschutz – Ausstieg aus der betäubungslosen Ferkelkastration [Internet]. 16 Mar 2021. Available from: https://www.bmel.de/DE/themen/tiere/tierschutz/ferkelkastration201811.html

[83] Wagner B, Royal K, Park R, Pairis-Garcia M. Identifying barriers to implementing pain management for piglet castration: A Focus Group of Swine Veterinarians. Animals. 2020;**10**(7):1202. Available from: https://www.mdpi.com/2076-2615/10/7/1202/htm

[84] Jacobs L, Neary J. Castration in the U.S. Swine Industry: Animal Welfare Implications and Alternatives. 2020. Available from: https://www.ext.vt.edu

[85] Ison SH, Rutherford KMD. Attitudes of farmers and veterinarians towards pain and the use of pain relief in pigs. The Veterinary Journal. 2014;**202**(3):622-627

[86] Prunier A, Bonneau M, von Borell EH, Cinotti S, Gunn M, Fredriksen B, et al. A review of the welfare consequences of surgical castration in piglets and the evaluation of non-surgical methods. Animal Welfare. 2006;**15**(3):277-289. Available from: https://www.cambridge.org/core/journals/animal-welfare/article/abs/review-of-the-welfare-consequences-of-surgical-castration-in-piglets-and-the-evaluation-of-nonsurgical-methods/D2BBF2A544789764798E5BEC87C0E819

[87] Fredriksen B, Font I, Furnols M, Lundström K, Migdal W, Prunier A, et al. Practice on castration of piglets in Europe. Animal. 2024;**3**(11):1480-1487. Available from: https://www.cambridge.org/core/journals/animal/article/abs/practice-on-castration-of-piglets-in-europe/FEF2FD38B0D58FDBF139A4ED58DFA54A

[88] Saller AM, Werner J, Reiser J, Senf S, Deffner P, Abendschön N, et al. Local anesthesia in piglets undergoing castration—A comparative study to investigate the analgesic effects of four local anesthetics on the basis of acute physiological responses and limb movements. PLoS One. 2020;**15**(7):e0236742. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0236742

[89] Rault JL, Lay DC, Marchant JN. Castration induced pain in pigs and other livestock. Applied Animal Behaviour Science. 2011;**135**(3):214-225

[90] Carroll JA, Berg EL, Strauch TA, Roberts MP, Kattesh HG. Hormonal profiles, behavioral responses, and short-term growth performance after castration of pigs at three, six, nine, or twelve days of age. Journal of Animal Science. 2006;**84**(5):1271-1278. DOI: 10.2527/2006.8451271x

[91] Taylor AA, Weary DM, Lessard M, Braithwaite L. Behavioural responses of piglets to castration: The effect of piglet age. Applied Animal Behaviour Science. 2001;**73**(1):35-43

[92] Tomasevic I, Bahelka I, Čandek-Potokar M, Čítek J, Djekić I, Djurkin Kušec I, et al. Attitudes and beliefs of eastern European consumers towards piglet castration and meat from castrated pigs. Meat Science. 2020;**160**:107965

[93] García GJ. Caracterización y eficiencia de agroecosistemas para una producción de cerdos Ibéricos más sustentable. Córdoba, Spain: Universidad de Córdoba; 2021

[94] Sødring M, Nafstad O, Håseth TT. Change in Norwegian consumer attitudes towards piglet castration: Increased emphasis on animal welfare. Acta Veterinary Scandinavian. 2020;**62**(1):1-9. Available from: https://actavetscand.biomedcentral.com/articles/10.1186/s13028-020-00522-6

[95] Pereira Pinto R, Vaz-Velho M. A perspective of the Portuguese consumer awareness, beliefs and preferences towards piglet castration methods and its implications on the meat quality. Agronomy Research. 2021;**19**(Special Issue 3):1273-1284. Available from: https://dspace.emu.ee//handle/10492/6529

[96] Baird AN. Chapter 13 – Swine surgery. In: Hendrickson DA, Baird AN, editors. Turner and McIlwraith's Techniques in Large Animal Surgery. 4th ed. Oxford, United Kingdom: John Wiley & Sons, Ltd; 2013. pp. 211-234

[97] Callan RJ, Hackett RP, Fubini SL. Chapter 27 –Surgery of the swine reproductive system and urinary tract. In: Fubini SL, Ducharme NG, editors. Farm Animal Surgery. 2nd ed. St. Louis, Missouri, USA: W. B. Sauders; 2017. pp. 617-632

[98] SMT R, Morrone S, Akl T, Scanu A, Columbano N. Sutureless technique for surgical castration in adult boars: A feasibility study. Animals. 2023;**13**(3):407. Available from: https://www.mdpi.com/2076-2615/13/3/407/htm

[99] Morales J, Dereu A, Manso A, de Frutos L, Piñeiro C, Manzanilla EG, et al. Surgical castration with pain relief affects the health and productive performance of pigs in the suckling period. Porcine Health Management. 2017;**3**(1):1-6. Available from: https://porcinehealthmanagement.biomedcentral.com/articles/10.1186/s40813-017-0066-1

[100] European Commission. Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the Protection of Animals Used for Scientific Purposes. Official Journal of the European Union; 2010. p. 276, 33-79

[101] Ahmed S, Jiang X, Liu G, Sadiq A, Farooq U, Wassie T, et al. New trends in immunocastration and its potential to improve animal welfare: A mini review. Tropical Animal Health and Production. 2022;**54**(6):1-10. Available from: https://link.springer.com/article/10.1007/s11250-022-03348-8

[102] Coutant M, Malmkvist J, Foldager L, Herskin MS. Relationship among indicators of pain and stress in response to piglet surgical castration: An exploratory analysis. Journal of Veterinary Behavior. 2023;**67**:20-32. DOI: 10.1016/j.jveb.2023.07.001

[103] Sheil M, Polkinghorne A. Optimal methods of documenting analgesic efficacy in neonatal piglets undergoing castration, Animals. 2020;**10**(9):1450. Available from: https://www.mdpi.com/2076-2615/10/9/1450/htm

[104] Karaconji B, Lloyd B, Campbell N, Meaney D, Ahern T. Effect of an anti-gonadotropin-releasing factor vaccine on

sexual and aggressive behaviour in male pigs during the finishing period under Australian field conditions, Australian Veterinary Journal, 123. 2015;**93**(4):121. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/avj.12307

[105] Baumgartner J, Laister S, Koller M, Pfützner A, Grodzycki M, Andrews S, et al. The behaviour of male fattening pigs following either surgical castration or vaccination with a GnRF vaccine. Applied Animal Behaviour Science. 2010;**124**(1-2):28-34

[106] Rydhmer L, Lundström K, Andersson K. Immunocastration reduces aggressive and sexual behaviour in male pigs. Animal. 2010;**4**(6):965-972. Available from: https://www.cambridge.org/core/journals/animal/article/abs/immunocastration-reduces-aggressive-and-sexual-behaviour-in-male-pigs/535F575B73AD3E5A36FF5F3104B65FD8

[107] Kress K, Millet S, Labussière É, Weiler U, Stefanski V. Sustainability of pork production with immunocastration in Europe. Sustainability. 2019;**11**(12):3335. Available from: https://www.mdpi.com/2071-1050/11/12/3335/htm

[108] Weiler U, Isernhagen M, Stefanski V, Ritzmann M, Kress K, Hein C, et al. Penile injuries in wild and domestic pigs. Animals. 2016;**6**(4):25. Available from: https://www.mdpi.com/2076-2615/6/4/25/htm

[109] Zoels S, Reiter S, Ritzmann M, Weiß C, Numberger J, Schütz A, et al. Influences of immunocastration on endocrine parameters, growth performance and carcass quality, as well as on boar taint and penile injuries. Animals. 2020;**10**(2):346. Available from: https://www.mdpi.com/2076-2615/10/2/346/htm

[110] Reiter S, Zöls S, Ritzmann M, Stefanski V, Weiler U. Penile injuries in immunocastrated and entire male pigs of one fattening farm. Animals. 2017;**7**(9):71. Available from: https://www.mdpi.com/2076-2615/7/9/71/htm

[111] Candek-Potokar M, Nieto R, editors. European Local Pig Breeds – Diversity and Performance. A Study of Project TREASURE. London, United Kingdom: IntechOpen; 2019. Available from: https://www.intechopen.com/books/9356

[112] Gómez-Fernández J, Horcajada S, Tomás C, Gómez-Izquierdo E, de Mercado E. The effect of immunocastration and surgically castration on growth performance and carcass quality in fattening period of Iberian female pigs. ITEA. 2013;**109**(1):33-48

[113] Podgórski T, Śmietanka K. Do wild boar movements drive the spread of African Swine Fever? Transbound Emerging Disease. 2018;**65**(6):1588-1596. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/tbed.12910

[114] Gamero-Negrón R, Sánchez del Pulgar J, Ventanas J, García C. Immune-spaying as an alternative to surgical spaying in Iberian×Duroc females: Effect on carcass traits and meat quality characteristics. Meat Science. 2015;**99**:99-103

[115] Di Martino G, Scollo A, Garbo A, Lega F, Stefani AL, Vascellari M, et al. Impact of sexual maturity on the welfare of immunocastrated v. entire heavy female pigs. Animal. 2018;**12**(8):1631-1637

[116] Andersson K, Brunius C, Zamaratskaia G, Lundström K. Early vaccination with Improvac®: Effects on performance and behaviour of male pigs. Animal. 2012;**6**(1):87-95. Available from: https://www.cambridge.org/

core/journals/animal/article/abs/early-vaccination-with-improvac-effects-on-performance-and-behaviour-of-male-pigs/3C5E619AB0A8B03432F4C6937D5E9C97

[117] Schmidt T, Calabrese JM, Grodzycki M, Paulick M, Pearce MC, Rau F, et al. Impact of single-sex and mixed-sex group housing of boars vaccinated against GnRF or physically castrated on body lesions, feeding behaviour and weight gain. Applied Animal Behaviour Science. 2011;**130**(1-2):42-52

[118] Cronin GM, Dunshea FR, Butler KL, McCauley I, Barnett JL, Hemsworth PH. The effects of immuno- and surgical-castration on the behaviour and consequently growth of group-housed, male finisher pigs. Applied Animal Behaviour Science. 2003;**81**(2):111-126

[119] Pesenti Rossi G, Dalla Costa E, Filipe JFS, Mazzola SM, Motta A, Borciani M, et al. Does immunocastration affect behaviour and body lesions in heavy pigs? Veterinary Sciences. 2022;**9**(8):410. Available from: https://www.mdpi.com/2306-7381/9/8/410/htm

[120] Argemí-Armengol I, Villalba D, Vall L, Coma R, Roma J, Álvarez-Rodríguez J. Locally grown crops and immunocastration in fattening heavy pigs: Effects on performance and welfare. Animals. 2022;**12**(13):1629. Available from: https://www.mdpi.com/2076-2615/12/13/1629/htm

[121] Millet S, Gielkens K, De Brabander D, Janssens GPJ. Considerations on the performance of immunocastrated male pigs. Animal. 2011;**5**(7):1119-1123

[122] Poulsen Nautrup B, Van Vlaenderen I, Aldaz A, Mah CK. The effect of immunization against gonadotropin-releasing factor on growth performance, carcass characteristics and boar taint relevant to pig producers and the pork packing industry: A meta-analysis. Research in Veterinary Science. 2018;**119**:182-195

[123] Dunshea FR, Allison JRD, Bertram M, Boler DD, Brossard L, Campbell R, et al. The effect of immunization against GnRF on nutrient requirements of male pigs: A review. Animals. 2013;**7**(11):1769-1778. Available from: https://www.cambridge.org/core/journals/animal/article/abs/effect-of-immunization-against-gnrf-on-nutrient-requirements-of-male-pigs-a-review/7F0B2ED611C0733686DC64AA65DD730B