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ADVANTAGES AND DRAWBACKS OF REARING ENTIRE MALE AND IMMUNOCASTRATED PIGS

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Invited paper

Abstract: Although surgical castration of piglets is still the predominant practice in Europe, rearing entire males (EM) or immunocastration (IC) are being increasingly used as alternatives. Present paper reviews the advantages and drawbacks of EM and IC concerning the animal welfare, productivity, pork quality, and public acceptance. Rearing of EM avoids the pain and infections associated with surgical castration while the problem of aggressiveness, injuries and stress appears during fattening. Thus from the animal welfare standpoint, IC is more favourable. Due to a better feed conversion and leanness, the rearing of EM is more profitable. However, costs occur due to slaughtering at lower weight, detection of boar taint and carcasses sorting at slaughter. The IC benefits the EM growth potential until the second vaccination, after which an accelerated growth occurs, accompanied by increased fat deposition. The main quality problem of EM meat is boar taint, however EM raw material exhibits other quality flaws related to fat tissue (low intramuscular fat, highly unsaturated fats), increased hardness of meat and lower water binding capacity. These drawbacks negatively affect the quality of meat products, though several strategies have been proposed to overcome the mentioned problems. The IC largely solves the problem of boar taint, its influence on meat quality looks positive but needs more research to further substantiate that. Stakeholder acceptance of the alternatives is country dependent and influenced by familiarity with the agricultural sector.

Key words: pigs, entire males, immunocastration, pros and cons, welfare, productivity, product quality, acceptance

Introduction

In Europe, surgical castration of male piglets is still the predominant practice in pig husbandry. The main reason for this procedure is to prevent boar taint (an unpleasant meat and fat odor due to the substances skatole and androstenone) and to manage aggressive and sexual behavior specific to male animals (*Bonneau and Weiler, 2019*). Another positive aspect of castration is

ensuring high meat and fat quality and consequently high quality meat products (*Škrlep et al., 2020a*). However, the practice of castration, when performed without pain relief (i.e., anesthesia and analgesia), causes great public concern (*Prunier et al., 2006*). Due to increased public awareness of animal welfare, many stakeholders in pig production sector are seriously considering or are already implementing alternatives. Raising uncastrated (entire) males (EM) is the most likely alternative to be implemented. This practice has long been used in countries such as the United Kingdom, Ireland, Portugal, and Spain and is gradually being introduced in several Western European countries or pork production chains (*Čandek-Potokar et al., 2015*). Although rearing EM means avoiding the act of castration, it still remains problematic from an animal welfare point of view, and the economic aspect of this alternative must also be considered, in terms of better productivity compared to some other processing-related costs and poorer meat quality (*de Roest et al., 2009; Čandek-Potokar et al., 2015*).

Figure 1. List of strengths, weaknesses, opportunities and threats of rearing entire male pigs

Regarding the rearing of immunocastrates (IC), this alternative is introduced in Europe at somewhat lower level. Despite solving several problems related to animal welfare (aggression, possibility to castrate old boars) and potentially being more suitable for some specific rearing systems (free-range, heavyweight, organic), the introduction of IC is mostly challenged by acceptance problems (*Čandek-Potokar et al., 2015; Fontanesi et al., 2017*). In immunocastration, androgen deprivation is achieved much later in the pig's life than in classical castration. To achieve a physiological response (i.e., immunize the organism against its own gondadotropin-releasing hormone (GnRH)), two consecutive administrations of an anti-GnRH vaccine are required, at least four weeks apart, with the second dose administered four to six weeks before slaughter. A rapid switch in IC metabolism occurs, increasing feed intake and promoting growth and fat deposition (*Claus et al., 2007; Batorek-Lukač et al., 2016*). Effective elimination of boar odor is also achieved rapidly, after as little as two weeks according to some literature (*Lealiifano et al., 2011*).

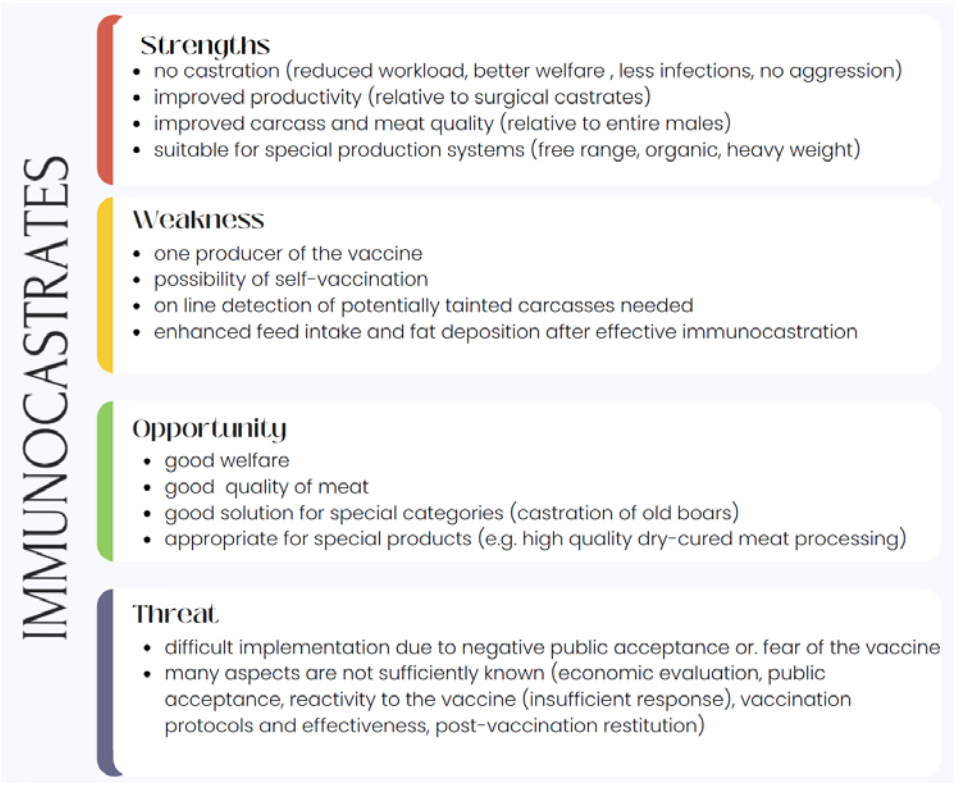

Figure 2. List of strengths, weaknesses, opportunities and threats of rearing immunocastrates

Welfare and management

Raising EM improves their welfare, at least early in life. They are not subjected to the pain and discomfort associated with surgical castration and postoperative complications (*Prunier et al., 2006; von Borell et al., 2009*). On the other hand, welfare may be significantly affected later in life when EM reach sexual maturity. The EM exhibit more aggressive and sexual behaviour (mounting) and are more active overall than surgically castrated males (SC) (*von Borell et al., 2009*). This manifests itself in constant confrontations between pen mates or harassment by the dominant animals. It leads to skin, ear, tail, and penis injuries, as well as lameness and leg damage (*Rydhmer et al., 2006; Weiler et al., 2016*). The problems are more commonly observed where either feeding sites or access to food is limited (*Velarde, 2007*). Increased fighting activity is also observed during regrouping (e.g., during transport or prior to slaughter) when stable rank relationships are lost (*Rydhmer et al., 2006*). Higher age at slaughter increases the risk of injury (*Weiler et al., 2016*), whereas rearing in mixed-sex groups does not seem to affect aggressiveness. The most pragmatic solution to this problem is to slaughter EM at a lower age, before reaching puberty, and/or provide an enriched environment (roughage, deep litter), adequate (feed) space, and avoid breaking up established social groups (*von Borell et al., 2020*).

In immunocastration, pain is limited only to the insertion of the needle during vaccination and is therefore considered more welfare friendly, avoiding acute pain and postoperative complications associated with surgical castration (*Prunier et al., 2006*). The literature reports either no or minor short-term reactions to the vaccine (*Einarsson, 2006*). Immunocastration reduces the aggressive and sexual behavior characteristic of EM shortly after effective immunization, as it would otherwise (considering the standard vaccination protocol) begin at 5 months of age with the onset of sexual maturity (*Zamaratskaia et al., 2008; Rydhmer et al., 2010*). This is important not only during rearing, but also in the pre-slaughter period (transport, rearing), where possible mixing of animals may trigger additional aggression related to hierarchy restoration (*Bolhuis et al., 2005*). As indicated by the incidence of carcass skin lesions and blood cortisol levels, IC showed intermediate levels of aggression compared to EM and SC. Certain rearing practices, such as restrictive feeding, can raise aggression levels back to those of EM (*Batorek et al., 2012a*). It has been suggested that the appetite of IC is greatly increased after the second vaccination (feed intake often even exceeds that of SC) and stress due to feed restriction is therefore much greater. It has also been pointed out that severe restriction (as practiced during certain periods in free-range Iberico pigs) may even significantly reduce vaccination success, thus requiring an adjustment of the feeding regime (*Hernandez-Garcia et al., 2016*). Nevertheless,

immunocastration could prove beneficial in free-range systems, as it can be used for both males and females and could provide management benefits (no need to separate males and females) in addition to animal welfare (no castration of males or females) and economic benefits (higher growth, more homogeneous herd) (*Martinez-Macipe et al., 2016; Fernandez-Moya, 2011*). Energy restriction or feed dilution could be a solution to control excessive fat deposition after effective vaccination (*Batorek Lukač et al., 2021*). Another welfare-friendly practice would be immunocastration of adult boars from artificial insemination stations. Although some studies suggest that this is successful in this age class, the exact timing of boar odor elimination, vaccination protocol, interfering factors still need to be investigated (*Fontanesi et al., 2017*).

Productivity and economic aspects

Compared to castration, breeding EM may be more economically advantageous for breeders. There are no castration costs and no losses due to infection of castration wounds. In standard production systems, EM has better feed conversion (up to 15% more efficient), which is related to lower ad libitum feed intake (up to 9% less feed consumption), and exhibit higher carcass leanness (up to 20%) compared to SC. Depending on the study report, growth rate can vary significantly, with some studies indicating up to 13% higher values in EM (*Bonneau and Weiler, 2019; Lundström et al., 2009*). The reason for this lies in their metabolic status. Regarding testicular hormones (androgens, estrogens), EM exhibits a strong protein anabolic state, reducing protein degradation and promoting protein build-up and lipid catabolism (*Claus et al., 1994*). Compared with SC, the average economic benefit of raising EM in a standard production system in the Netherlands and France has been estimated at 7 to 8 EUR/pig (*ALCASDE, 2009*), including the reduction in income due to carcass sorting and a possible decrease in the price of taintedmeat (2%). In another estimate (*Béteille, 2014*), the surplus has varied between 5.2 and 10.8 EUR/pig. It should be noted here that certain additional costs are still difficult to evaluate. In some EU countries such as the UK, Ireland, Spain and Portugal, boars are slaughtered at lower weight before they reach sexual maturity. This may also imply higher herd turnover, higher demand for young piglets, lower carcass dressing and additional treatment at slaughter (removal of the reproductive tract) and consequently higher slaughter costs when calculated per kg of meat (*de Roest et al., 2009*); not to mention losses due to higher aggressiveness and potential market losses (due to negative consumer reactions to boar taint or low-quality meat products, *Fontanesi et al., 2017*). It is also worth noting that standard swine production does not cover all the specific needs of the swine sector (i.e. better quality, fatty raw material for high value meat

products). In situations where high weights or age are involved (e.g., local breeds, free-range), it is not practically feasible to raise sexually mature EM (*Fontanesi et al., 2017*), so the use of other (castrated) categories of pigs remains essential.

As for IC, this category grows faster than SC or even faster than EM, considering the total fattening period (from first vaccination to slaughter) and the standard vaccination protocol. However, the IC consume more feed than EM, but less than SC. Therefore, feed conversion of IC is better than that of SC and only slightly worse than that of EM (meta-analysis by *Batorek et al., 2012b*). The reason for this is that IC is physiologically equivalent to EM until the second inoculation, allowing them to utilize their boar-like growth potential. Thereafter, rapid physiological changes (namely a drop in steroid hormone levels accompanied by relatively high IGF-1 and growth hormone levels and low leptin concentration) trigger high feed intake and accelerate growth (*Batorek et al., 2012a; Kubale et al., 2013*). It should be noted that protein deposition remains about the same, while IC mainly increase deposition (*Batorek Lukač et al., 2016*). However, the level of fat deposition in IC depends on the timing of immunisation relative to slaughter. The more time elapses between the second immunisation and slaughter, the higher the fat deposition (*Škrlep et al., 2014*), which negatively affects the economics of rearing (higher fat content leads to lower carcass leanness, which lowers the price). In general, IC pigs have greater backfat thickness compared to EM, resulting in lower lean carcass content, while a comparison of IC with SC shows the advantages of the former (lower fat carcass content, heavier hams and shoulders; *Batorek et al. (2012b*)).

The cost of immunocastration includes the price of the vaccine and the additional workload due to vaccination. On the other hand, this is compensated by higher feed conversion, faster growth, and a leaner carcass compared to SC (*Batorek et al., 2012a,b*). Although actual costs are difficult to assess due to price variations in labour, equipment, pharmaceuticals, and pig production parameters, it has been estimated (*de Roest et al., 2009*) that the direct additional cost of immunocastration ranges from 3.00 to 3.65 EUR/animal (excluding the price of slaughter line carcass examination for boar taint and additional carcass trimming). This is more than the estimated cost of surgical castration (estimated between 0.78 and 2.99 EUR, *de Roest et al., 2009; Rodriguez-Estevez et al., 2012*) or about the same if pain relief is administered (0.19 to 1.67 EUR/piglet;; *de Roest et al., 2009; Aluwe et al., 2012*). At the same time, faster growth and better feed conversion takes place compared to SC (for which reports range from 8% to 18%, depending on the breed used, *Škrlep et al., 2010; Batorek et al., 2012a*), generally resulting in an economic advantage reported in various studies to be -0.02 to + 0.12 EUR/kg (*de Roest et al., 2009; Kastelic and Košorok, 2010; Aluwé et al., 2012*). Another study by *de Roest (2015)* indicated the advantages of immunocastration over

surgical castration in terms of lower infection rates (estimate: 2.75 EUR/pig). Although immunocastration does not have a large economic impact, it would also be beneficial for culled boars used for breeding or performance testing. These animals are often sold for slaughter at a very low price. Alternatively, if they are castrated by a veterinarian, this adds costs, not to mention the welfare aspects of this rather demanding procedure. However, a recent study has shown that a two-dose vaccination regimen results in progressive but variable regression of testicular function in culled boars, insufficient to elicit a complete immunocastration response in all animals (*Batorek-Lukač et al., 2022*). Therefore, a suitable vaccination regimen must be investigated for these animals.

Another important aspect is the need for classification/scanning of carcasses at both EM and IC, in order to sort out tainted carcasses (including IC, which did not respond properly to the vaccine). As described by *Font i Furnols et al. (2020)*, numerous methods have been developed so far, including those based on human assessors, chemical, physical, or spectroscopic methods. However, almost all of them have certain drawbacks related to low sample capacity, speed, price, or lack of suitability for online use; many of them still need to be sufficiently developed. Nevertheless, a recent study shows that testicular weight could be a reliable indicator of androstenone-positive carcasses (IC), while at EM the difference in testicular size between EM with androstenone levels below and above the risk threshold was less pronounced, but urogenital tract weight was reliable in these animals (*Fazarinc et al., 2023*).

Meat, fat and product quality

In general, castration in pigs leads to increased fat deposition with a concomitant increase in fat saturation (*Wood et al., 2008*). Comparing the different male sex categories, fat content and fat saturation decrease in order SC > IC > EM, although the differences vary considerably due to factors such as age, feeding, and IC vaccination timing. Interestingly, higher polyunsaturated fatty acid (PUFA) content is observed in EM, even with the same fat thickness as in SC (*Škrlep et al., 2020a*). The fat of EM may be more susceptible to oxidation (*Babol et al., 1995*), although scientific evidence for this is lacking. Compared to SC, the fat of EM contains fewer lipids, more water, and connective tissue and is therefore softer, less cohesive, and poorly attached to underlying tissues (*Wood et al., 1982*). This poses a major problem when integral meat cuts are further processed. Another problem with EM is the extreme carcass leanness along and low intramuscular fat (IMF) content (*Škrlep et al., 2020b*), which negatively affects final product characteristics such as juiciness, tenderness, flavor, and processing results (*Škrlep et al., 2020a*). At IC, the most pronounced physiological changes following effective

immunization relate to increased fat synthesis (*Batorek-Lukač et al., 2016*). Indeed, carcass fat content increases proportionally to the interval between slaughter and the second vaccination (V2-S, *Lealiifano et al., 2011*), with lipid deposition being somewhat depot-dependent (leaf fat and back fat deposit faster than IMF (*Poklukar et al., 2021*). Fatty acid composition also changes very rapidly, from EM to SC within 6-9 weeks (*Tavarez et al., 2014a*), so this interval should be extended if processing into high-value meat products is planned (preference for more saturated fat).

Regarding technological meat quality traits such as colour, pH, and water holding capacity (WHC), available meta-analytical studies (*Pauly et al., 2012; Batorek et al., 2012b; Trefan et al., 2013*) suggest that there are no or only minor and practically insignificant differences. Some older studies still show higher meat pH and the presence of dark, firm, and dry meat (DFD) in EM associated with higher aggression and stress, resulting in muscle glycogen utilisation during pre-slaughter procedures (*Sather et al., 1995*). In contrast, recent research suggests that male sex categories do not respond differently to stress and meat quality is barely affected (*Holinger et al., 2018*). There is still some evidence for a stronger red meat coloration of EM, either related to the previously mentioned mechanisms of glycogen degradation, a more oxidative metabolic profile, or a lower IMF (*Škrlep et al., 2020a*). Although again of little practical significance, IC have been shown to have lighter muscle colour, most likely due to higher IMF and lower WHC (*Pauly et al., 2012; Batorek et al., 2012b; Trefan et al., 2013*). Regarding the different WHC characteristics, SC has generally been reported to have a better water binding capacity compared to EM or IC, but again this is highly study dependent. Nevertheless, some studies show that the drip loss for EM is up to 45% higher than for SC, with the most likely cause being oxidation of the unsaturated fats during heat treatment (*Škrlep et al., 2019*). The oxidation-induced lower WHC value as well as the higher collagen content in the meat of EM, were associated with the higher muscle toughness of this male sex category, while IC was still between EM and SC (*Škrlep et al., 2019; 2020b*). According to the reports of these studies, 20-25% higher shear forces were measured at EM. Nevertheless, the toughness issue remains poorly addressed, while some other processes (such as the higher proteolytic potential of EM) offer the possibility to address this drawback.

High-quality raw material is essential for the production of high-quality meat products (e.g., dry-cured products such as hams, sausages, pancetta). The more aggressive behaviour of EM often leads to a higher incidence of skin lesions on the carcass (cuts, hematomas, bruises; *Batorek et al., 2012a*), which either affect the external appearance of the product or (in case of more profound damage) trigger bacterial spoilage (*Čandek-Potokar & Škrlep, 2012*). The use of EM raw material can lead to several disadvantages related to the previously mentioned low

amount of subcutaneous fat or IMF or inferior WHC, including high processing losses, excessive salt intake, and the development of an inappropriate (hard) texture and poor flavour development, as seen in either dry-cured ham (*Čandek-Potokar et al., 2020*), dry-fermented sausages (*Corral et al., 2016*), or cured belly (*Smith et al., 1983*). However, problems related to oxidation have not been reported in the literature, but this could be due to the use of antioxidants (i.e., nitrites, ascorbates) used in the majority of meat processing formulations (*Škrlep et al., 2020a*). Interestingly, EM bacon was found to be better accepted by consumers than SC bacon because it was leaner, even when boar taint was present in the samples (*Čandek-Potokar et al., 2019*). As for the use of IC, for example, the application of the standard inoculation protocol (V2-S of 4-5 weeks) resulted in dry-cured hams still more similar to EM than SC (except for the absence of boar taint) (*Čandek-Potokar et al., 2020*). Similarly, such immunocastration protocol resulted in leaner cured bellies that were also better accepted by consumers, but with a lower slicing yield (*Tavarez et al., 2014b*). Extending the V2-S period to 6-9 weeks or even vaccinating 3 times (as practised in heavy pigs) mainly eliminated the differences toward SC in dry-cured ham (*Škrlep et al., 2016; Pinna et al., 2015*) or bacon (*Tavarez et al., 2014b*).

The main drawback of processing raw material from EM is the possible presence of boar taint. To mitigate this risk, there are several strategies depending on the composition of the raw material (fat and boar taint content), the specific processing method, the masking strategy used, or the type of consumption (cold or hot) (*Škrlep et al., 2020a*). Dry curing or dry fermentation processes have not been found to sufficiently reduce or mask the concentration/perception of boar taint in dry cured ham (*Diestre et al., 1991*) or sausages (*Corral et al., 2018*). An advantage of these products is that they are usually consumed cold, which somewhat reduces the risk of negative perception, but only for products with low to moderate off-flavour (below 0.8-1.0 ppm androstenone). For sausages, a low level of masking can be achieved by microbial fermentation (addition of starter cultures), addition of spices, or chemical additives (polyphosphates, acidifiers) (*Corral et al., 2017, 2018*). Smoke, on the other hand, has been identified as a relatively efficient masking agent that can manage higher levels of boar taint in various types of sausages or other types of meat products when used intensively (*Aaslyng et al., 2018*) or in combination with dilution (mixing 25% to 50% tainted with untainted meat, *Meier-Dinkel et al., 2016*) where this process is applicable (*Škrlep et al., 2020a*). Products such as cooked ham, bacon, cooked sausages, minced meat patties, etc. are usually consumed hot/warm, which greatly increases the potential perception of boar taint especially during preparation (evaporation in the room). However, thermal treatment itself can reduce boar taint compounds in the product to some extent, but only if high temperatures are applied for a long period of time

(*Peñaranda et al., 2017*). Additional masking measures such as frying in oil (as a source of aroma compounds), applying different marinades with spices such as garlic, parsley, curry, oregano, and fennel, and embedding meat in breadcrumbs or combining tainted meat with a complex meal (e.g., with bread and cheese) have been confirmed to be effective for low to moderate levels of boar taint (*Škrlep et al., 2020a*).

Public acceptance

While acceptance for EM is quite good in countries where it is already produced, raising EM for meat consumption is new to many European countries. There, consumer acceptance of alternatives to surgical castration is generally understudied (*Fontanesi et al., 2017*). Most EU consumers are unaware of the problem of boar taint and do not even associate pork with castration (*Kallas et al., 2013*). A study conducted in 13 Eastern European countries (*Tomašević et al., 2020*) showed that awareness of pig castration is also low. Nevertheless, consumers expect meat to be safe, healthy, and tasty, and therefore may be susceptible to the problem of boar taint. As indicated in the PIGCAS project report (*PIGCAS, 2009*), pig producers and consumers were reluctant to adopt EM, preferring the traditional practice of surgical castration. According to more recent reports (*Fontanesi et al., 2017*), the attitude of some stakeholders in some production chains has partially changed in some countries, such as France, Belgium, Germany, and the Netherlands, where a larger proportion of EM is produced. Nevertheless, there are large differences between production chains and their willingness to produce EM, both within countries that have recently started producing EM and between countries. The recent trend observed in some countries to increase the production of EM applies only to standard production systems. On the other hand, raising EM in special production systems (i.e., heavy pigs, high value products) still raises concerns about management (EM aggressiveness, farmer safety), meat quality (too lean meat), and product specification (higher age and weight requirements).

Regarding existing studies on IC, acceptance within Europe is again highly country dependent. German consumers of organic pork rated EM better than IC, and the latter were rated better than SC (*Heid and Hamm, 2013*). In Sweden, consumers rated IC more positively than rearing EM or surgical castration without anaesthesia (*Lagerkvist et al., 2006*). In contrast, according to *Huber-Eicher et al. (2011)*, Swiss consumers rejected IC compared to surgical castration, but when it was performed with pain relief. Similar results were obtained by *Fredriksen et al. (2011)* in Norway. In both countries, anaesthesia is already required for surgical castration. In the Belgian study (*Tuyttens et al., 2011*), IC was also rated as very favourable, but only after thorough information about all possible alternatives,

indicating the importance of consumer education. In the broader survey (*Fontanesi et al., 2017*), stakeholders in the pig production chain across Europe (including pig producers, meat processors, veterinarians, and slaughterhouses) still rated the prospects of IC as low, with the main reason being the fear of negative consumer reactions hindering its implementation. Other disadvantages cited include labour safety measures, additional workload, and lack of information on specific issues (restitution after vaccination, adaptation of vaccination protocols to specific production systems, lack of experience, and vaccination success). Consumers question the practice of IC from a food safety point of view or prefer less use of drugs, fear residues, unknown long-term effects and unnaturalness (*Mancini et al., 2017, 2018; Fredriksen et al., 2011*). On the other hand, a comprehensive international study (*Vanhonacker and Verbeke, 2011*) conducted in France, Germany, and the Netherlands, with over 4000 respondents, showed that concerns about negative reaction to IC may be overstated, as the method itself was acceptable to more than 70% of respondents. As for Norwegian and Italian consumers, one of the reasons for accepting IC was trust in their national food safety institutions (*Fredriksen et al., 2011; Mancini et al., 2018*). Animal welfare-oriented nongovernmental organisations also rated IC as acceptable, although they preferred EM. Scientific experts viewed IC as a much better alternative to SC with pain relief, as they believed it improved animal welfare and was also more economical and easier to implement (*PIGCAS, 2009*).

Conclusion

As recent trends show, the rearing EM is gradually gaining importance in the EU despite several welfare and meat quality related drawbacks. Although the immunocastration solves many of these issues (i.e. prevents boar taint, welfare problems, improves meat and fat quality compared to EM, improves productivity compared to SC), this practice has not gained much interest in the sector, at least in Europe. Fear of the public acceptance remains the main obstacle for its use. Regardless of the anticipated changes concerning the ban on castration without anaesthesia, these changes are only happening slowly, whereas the introduction of various alternatives will most probably depend on the different needs of individual niches in pig production.

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