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# Marinade injection of pork as a possible technological strategy to reduce boar taint: Response and attitude of the consumer

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ABSTRACT

Sensory evaluation by consumers allows validation of a solution for the food industry to overcome boar taint and market entire male pork with high levels of boar taint considered "unfit for human consumption". One possible technological strategy for improvement is the injection marination of entire male pork to help minimise the impact of boar taint and improve its marketability. The responses of 120 regular pork consumers, to entire males with high levels of boar taint and castrated pork, both injection-marinated, were evaluated. The results showed a similar response between entire and castrated male pork regardless of sex, and the detection of unpleasant odours and flavours (as farm/animal), thus offering a new alternative to the pork sector to mask the boar taint and revalue this pork. However, it was observed that consumer information on castration and animal welfare of entire male pork is scarce, and it is important to increase their knowledge so that they can place a value on this technological strategy with entire male pork and thus increase their purchase intention.

## 1. Introduction

Surgical castration of piglets was a very common practice to increase the fat content of the carcass and prevent the pork from acquiring an unpleasant odour and flavour at the time of consumption, called boar taint. However, this practice has been questioned in the European Union as a painful procedure that does not guarantee the animal's welfare (European Declaration on Alternatives to Surgical Castration, 2010). Due to this, pig production has shifted towards rearing entire male pigs, as it is considered the most humane and cost-effective alternative to surgical castration without anaesthesia and/or analgesia (Bonneau & Weiler, 2019), although this practice may involve the presence of boar taint caused by the accumulation of androstenone (AND) and skatole (SKA) and other indoles in fat and lean tissues. The AND (5α-androst-16-ene-3one) is a testicular steroid with an odour similar to urine or sweat (Lunde et al., 2012), and is perceived by approximately 40–50% of consumers, with this sensitivity having a strong genetic basis (Font-i-Furnols, 2012). Based on the existing literature, a genetic predisposition to the odour and flavour of androstenone has been observed among women, which would increase their sensitivity (Voznessenskaya & Klyuchnikova, 2017), and they may react adversely to this pork if these compounds are not to their liking (Panella-Riera et al., 2016). However, the SKA (3-methyl-indole) is a metabolite of the amino acid tryptophan, with faecal, naphthalene-like odour (Pauly et al., 2010), and the most consumers are sensitive (Borrisser-Pairó et al., 2016). Levels of these compounds in pork can be affected by management practices, nutrition, and to a greater extent by the animal's sexual maturity and genetics (Squires et al., 2020). Therefore, reliable solutions are needed to process entire male pork affected by boar taint into acceptable products for consumers.

Immunocastration has been shown to be an effective control of boar taint if applied correctly (Dalla Costa et al., 2020), and is widely used in Brazil, New Zealand and Australia (Squires et al., 2020), but has not been widely implemented in Europe or the USA, principally due to consumer concerns about vaccinated meat (Di Pasquale et al., 2020), perceived risks to farm workers and lack of acceptance of entire boars at slaughter facilities (Squires et al., 2020).

The perception of boar taint varies between different pork products. In general, fresh meat such as loins, shoulder and bacon are accompanied by a higher risk for the presence of boar taint, especially when heated, as compared to processed meat products, which due to cooking, fermentation, smoking, and the use of spices, minimise the boar taint (Škrlep et al., 2020). Given the limitations that exist in masking strategies to ensure that fresh pork meets the sensory expectations of consumers, it is a major challenge to find alternative solutions that meet the current needs of the pig industry, to be able to market this fresh pork

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without detracting from consumer satisfaction. Sensory evaluation is a tool of great importance in all stages of production and development in the food industry, both for understanding the characteristics, and the acceptability and reception of a product by consumers, we can learn about consumer perceptions of a product and the degree to which these influence their purchasing decisions (Ruiz-Capillas et al., 2021). This is why sensory and consumer behaviour research is recognised as a key multidisciplinary science that encompasses different methodologies to guide the innovation process of the new boar taint masking strategies, to ultimately adapt products to the demands or needs of consumers without diminishing their sensory qualities (Aluwé et al., 2020; Grunert et al., 2011).

In fresh entire male pork, one of the most commonly used culinary strategies is marinating by immersing spices in various liquids (water, oil, wine, etc.). Lunde et al. (2008) reported the effect of marinating by immersing with oregano, garlic, and liquid smoke, on the reduction of boar taint in pork chops with different concentrations of AND and SKA was evaluated, and the results showed that it was able to reduce the perception of boar taint. Egea et al. (2018) showed that marinating by immersing with oregano, paprika, oil, vinegar, and water, decreased the perception of boar taint in pork loin. Injection marination has been shown to provide a greater and more homogeneous distribution and a more intense odour and flavour of spices in the pork (Istrati et al., 2015).

However, no studies have been found that evaluated the effect of this culinary injection technique on entire male pork for masking boar taint. Studies on entire male pork have only focused on assessing the sensory profile and the degree of marinade masking by immersion using a trained panel, therefore empirical studies on the effect of injection marinade on boar taint and consumer satisfaction and perception of these injected products are lacking, based on gender due to the genetic predisposition of boar taint among woman.

It would be interesting to find out whether regular pork consumers have received sufficient information about castration and animal welfare, and if they would be willing to buy entire male pork marinated by injection if the boar taint was masked, as a few years ago most consumers still did not have sufficient information on this topic (Aluwé et al., 2020). The objective was to evaluate consumer perception and attitude, according to sex, to injection-marinated entire male pork as a strategy to reduce boar taint.

## 2. Material and methods

### 2.1. Pork samples

The entire and castrated animals used in this study complied with EU guidelines for the care and handling of research animals (Directive 2010/63/EU). The trained experts were selected by the human olfaction methodology (Font-i-Furnols et al., 2020), and thirty-one carcasses of entire male pigs with strong boar taint out of three hundred animals from a slaughterhouse located in Catalonia (Spain) were utilized. Fatty tissue from the dorsal neck region of these carcasses was analysed for androstenone by gas chromatography–mass spectrometry (GC–MS), and skatole using high-performance liquid chromatography (HPLC) (Garcia-Regueiro & Rius, 1998), to determine the highest concentrations of AND and SKA (5.511 μg/g of androstenone and 0.730 μg/g of skatole in the *longissimus thoracis et lumborum* muscle). The *longissimus thoracis et lumborum* muscles of castrated pigs (control), selected from the local butcher shop that certified the castration of these animals (0–0.3 μg/g of androstenone and $\leq$ 0.1 μg/g of skatole), and from entire male pigs, were cut in pieces weighing 300 g and stored refrigerated at 4 °C until marination. With an average time between processing of the meat piece in the slaughterhouse and cooking for sensory evaluation of 2 months and 5 days. The average time between processing of the meat piece in the slaughterhouse and cooking for sensory evaluation was 2 months and 5 days.

### 2.2. Marinade elaboration

The pork pieces were marinated by injection in the pilot plant located in a pork processing establishment that complied with the conditions of the health authorities. The marination of the pork pieces was carried out with a mixture of salts, seasonings, aromas, and white wine (Table 1) by applying 20% by injection into 300 g of meat. The injection was carried out with the help of an injection template (1 × 1 $cm^2$ squares) on both sides of the meat piece at 2 °C. After injection, the pieces were manually massaged for two 10-min cycles to allow the correct distribution of the mixture. The injected pieces were then stored at 6 °C for 24 h until cooking, in the following days, to ensure that the muscle was well impregnated with all the flavourings.

Three batches of each type of pork (castrated and entire male pork) were produced on different days within one week following the same process (replicates).

### 2.3. Pork cooking

Once the pork pieces were marinated, they were cut into 1.5 cm-thick fillets for cooking.

The fillets were cooked in a 26-cm frying pan with 4 mL of sunflower oil. The pan was preheated for 1 min (oil temperature 120 °C) at a moderate heat setting before the tenderloin samples were added. The fillets were cooked for 1 min on each side until a final temperature in the centre of the product of 72 °C was reached (Iniesta et al., 2023). Once cooked, they were cut into 2 cm × 2 cm squares and each portion was placed in an aluminium casserole dish and kept at 60 °C until tasting (Peñaranda et al., 2017). Cooking and tasting were conducted in separate rooms to avoid bias due to odour perception during cooking.

### 2.4. Consumer study

The study received ethical authorization from the ethics committee of the University of Murcia (reference number: 3566/2021). For this study, we use one hundred and twenty consumers who were randomly recruited by the company Global Sensory (Barcelona, Spain). They were evenly distributed into four age ranges (60 men and 60 women, 19–29 years old: 30 consumers, 30–45 years old: 30 consumers, 46–60 years old: 30 consumers, and > 60 years old: 30 consumers). The inclusion criterion was that they were regular consumers of pork and pork products (frequency of pork consumption two to three times a week or several times a month). The study was conducted according to ISO 8589, 2007 in a standardised room of this company in two sessions, carried out on consecutive days. A total of 60 consumers were involved in each session. All participants gave their written informed consent to participate in the study.

The consumer study was conducted with a questionnaire consisting of 4 parts. This questionnaire was developed from a thorough literature review on the castration of entire male pigs and the tools of sensory

**Table 1**
Formulation of spiced marinade ingredients (g/100 g of pork).

| Marinade | Injected |
|---|---|
| Tetrapotassium pyrophosphate (E-450) [1] | 0.5% |
| Salt[2] | 2% |
| Dextrose[1] | 1% |
| Sodium ascorbate[1] | 0.12% |
| White wine[3] | 15.4% |
| Powered black pepper[4] | 0.00007% |
| Powered nutmeg[4] | 0.07% |
| Powered ginger[4] | 0.06% |
| Lemon juice[5] | 0.11% |
| TOTAL | 20% |

[1]Natural de mezclas, Murcia, Spain; [2]Aliada, Madrid, Spain; [3]Don Simón-García Carrión, Murcia, Spain; [5]Hacendado, Valencia, Spain.

evaluation of consumer response (Aluwé et al., 2020; Girolami et al., 2014; Grunert et al., 2011).

Part 1: Evaluation of colour and appearance of a photograph (Fig. 1A) using a 9-point horizontal hedonic scale anchored on "I dislike it a lot" (1) and "I like it a lot" (9) (Wichchukit & O'Mahony, 2015). The participants had to answer whether they found it attractive and would buy it by looking at the image. The possible response options were: yes and no.

Part 2: Consumers were asked to rate the odour, flavour, hardness, juiciness, and acceptability of two samples of cooked marinated meat (castrated and entire male) using a 9-point horizontal hedonic scale (score from 1: I dislike it very much, to 9: I like it very much). Samples were randomly coded with three digits and presented randomly by type of meat (castrated and entire male). In addition, they were asked if they detected any strange odours/flavours (such as farm/animal), if they were highly seasoned, and about their intention to buy (response options: yes and no).

Part 3: An infogram on castration of entire male pigs (Fig. 1B) was presented, and consumers had to re-evaluate the acceptability and purchase intention of these samples, but in this case knowing the type of animal.

Part 4: Questioning their consumption habits (if they had ever experienced an unpleasant smell when consuming pork, if they knew that pigs were usually castrated without anaesthesia, if they would buy marinated pork if it eliminated the unpleasant odour/ flavour (such as farm/animal), and if they would be willing to pay more for a product that ensures animal welfare). All consumers completed all 4 parts of the questionnaire in the same session.

### 2.5. Statistical analyses

For statistical analysis and processing of the consumer survey data, the statistical software package SPSS 24 (SPSS, Chicago, IL) was used. The colour and appearance of the photograph (Part 1) were analysed using a one-way analysis of variance (ANOVA), considering sex (woman and men) as a fixed source of variation, and consumers, manufacturing replicates (three batches) and session were adjusted for random effects. For the sensory evaluation of injection marinated pork (Part 2), a multivariate analysis was performed using the General Linear Model (GLM) procedure, considering the type of pork (castrated and entire male), sex (woman and men) and consumers' ranking according to their experience in detecting unpleasant odour/flavour (such as farm/animal) when eating pork (yes or no), as fixed sources of variation, and consumers, manufacturing replicates and session as random effect. The assessment of acceptability after providing information on castration and under-information conditions on the type of meat evaluated (Part 3) was analysed using a two-way ANOVA considering the effect of type pork of marinated by injection (entire and castrated), and the effect of tasting (before and after consumers were informed), as fixed factors, and manufacturing replicates, session and repeated measures for each consumer as random factors. Data are presented as means, standard error (SE) and root mean square error (RMSE) for each variable. Comparisons between means were performed using Tukey's test, and differences were considered significant at the $P \leq 0$ level.

The frequency of "yes" or "no" to the questions asked in the questionnaire was determined through contingency tables, and the Chi-square Test was performed to identify significant differences ($P \leq 0.05$) between frequencies according to the variables studied (sex, type of meat, and consumers who detect unpleasant odour/taste when consuming meat) for each question. The data from the frequency analysis are presented using graphical illustrations and frequency tables.

## 3. Results and discussion

### 3.1. Part 1: photograph

The consumers' evaluation of the colour and appearance of the injection-marinated entire male pork is shown in Table 2, with maximum scores for women and men being 7.67–7.52 respectively. The incorporation of spices in the injection was done intramuscularly, not superficially thus providing a more homogeneous distribution (Casiraghi, Alamprese, & Pompei, 2007; Vaquero, 2013); hence the good

**Table 2**
Colour and appearance ratings[1] of pork photographic by consumers classified according to sex [mean and standard error (SE)].

| Sex | N | Colour | | Appearence | |
|---|---|---|---|---|---|
| | | Mean | SE | Mean | SE |
| Woman | 60 | 7.67 | 0.12 | 7.52 | 0.11 |
| Men | 60 | 7.37 | 0.10 | 7.27 | 0.12 |
| *P-value* | | 0.050 | | 0.141 | |

Values with significantly differ at $P \leq 0.05$.
[1] Scores from 1- dislike very much to 9-like very much.

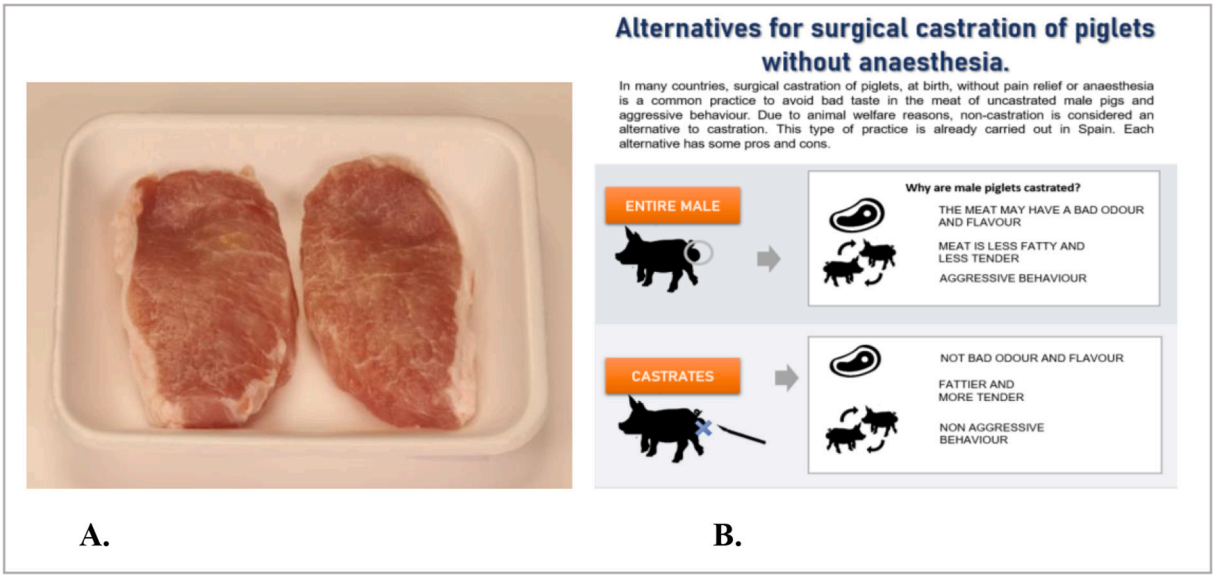


**Fig. 1.** Consumer questionnaire. A: photographic and B: information provided.

scores of the treatment provided by consumers. Regarding sex, significant differences ($P \leq 0.05$) were observed in the "like the colour" parameter, although they were not very relevant, with men providing a lower colour score to the treatment than women. For appearance, no significant differences were obtained between the different sexes ($P > 0.05$), with similar scores found for men and women.

Meat colour may be affected by the ingredients used in the marinade and therefore, the overall aspect may be different in the different samples. Vaquero (2013) observed that loin meat marinated with pigmented vegetable extracts had a more yellowish colour. Also in the work by Tänavots et al. (2018), the authors found higher values of yellowness in pork marinated with wine and apple cider vinegar. Therefore, the ingredients used in our treatment, especially the spices (ginger and nutmeg), lemon juice, and wine, could have affected the colour of pork. This could influence the colour score, especially for males doe to the higher myoglobin in their meat than in castrated pigs (Škrlep et al., 2019), as the yellow hue detracts from the more characteristic reddish colour of the meat.

Regarding the frequency of purchase intention and the appetite of the product, significant differences ($P \leq 0.05$) were observed among the consumers surveyed, who said "yes" or "no" to these questions, although no significant differences were observed according to sex ($P > 0.05$) and age ranges (data not shown). The injection-marinated pork was found to be appetizing to 96.70% of the total consumers, and 97.50% of the consumers stated that they would buy it (Fig. 2). Since the sensory properties of the product are unknown, consumers' expectations and the visual appearance of the product (attractive, appetizing, etc.) are crucial when purchasing a product for the first time (Font-i-Furnols et al., 2019; Grunert et al., 2011), hence the similarity of the consumers scores in both questions ("Would you buy it?" and "It is appetizing product?").

Therefore, the intention to purchase a product will largely depend on whether consumers perceive that these products are visually good (high quality) in new, more attractive formats that require less processing to be consumed (ready-to-eat products) (AECOC, 2021; Udomkun et al., 2018).

### 3.2. Part 2: sensory evaluation

Table 3 presents the results obtained after the sensory evaluation by consumers of entire male pork with high levels of boar odour and castrated pork, both marinated through injection. No statistically significant differences were observed for any of the sensory attributes ($P > 0.05$) between the variables studied (type of pork, sex and consumers who had previously experienced an unpleasant odour/flavour when consuming pork) with mean scores around 6.33–7.48, except for the odour of castrated pork between sexes ($P \leq 0.05$). In that case, women scored the odour of marinated meat of castrated pork higher than males, although the differences were slight between sexes.

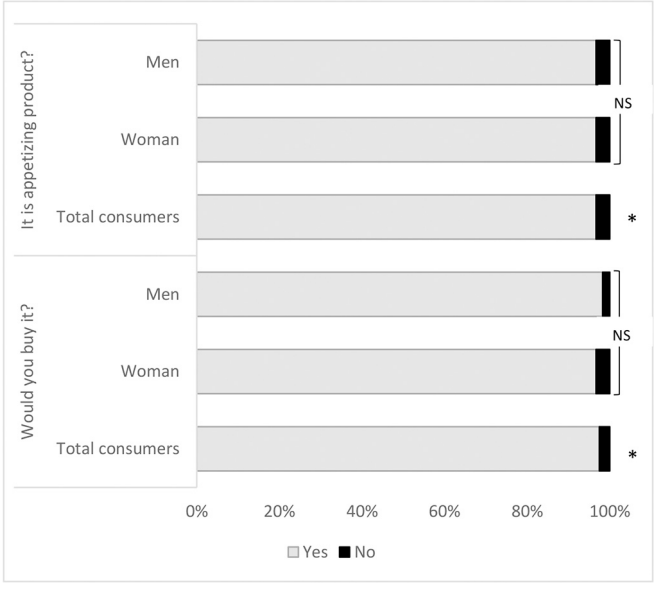


**Fig. 2.** Frequency of 'yes' and 'no' answers on purchase intention and finding the product appetizing among consumers classified according to sex.
NS: non-significant differences ($P > 0.05$), *: significant differences ($P \leq 0.05$).

High levels of AND and SKA do not seem to affect the acceptability of entire male pork to consumers, since the marination by injection resulted in the good sensory quality of entire male pork. Therefore, the incorporation of the spices (and therefore aroma) by injection, provided more intense odours and flavours that allowed masking of unpleasant odours and flavours (Vaquero, 2013).

The use of flavourings with a very pungent odour, such as nutmeg and ginger, helps to improve the sensory quality of entire male pork, by masking unpleasant aromas and flavours (Aaslyng et al., 2015; Chatterjee et al., 2015). In addition, entire male pork has a lower adiposity, water holding capacity and higher meat toughness, resulting in tougher and less juicy meat (Škrlep et al., 2020). It is well known that castration increases fat deposition in pigs and the intensity of post-mortem muscle metabolism, so that under identical rearing conditions entire male pigs tend to have less intramuscular fat and harder muscles than castrated pigs, affecting meat tenderness (Škrlep et al., 2020; Van den Broeke et al., 2022) and thus consumer acceptability (Felderhoff et al., 2020). Furthermore, boar taint compounds are correlated with fatty acid composition (Wauters et al., 2016), being higher for androstenone due to its lipophilic characteristics. Therefore, entire male pork with high concentrations of boar taint has a high PUFA content even at the same fat thickness as meat from castrated pigs, due to differences in lipid metabolism during growth (Škrlep et al., 2020). In this study, entire and castrated male pork had a very similar intramuscular fat percentage (not as usual in commercial conditions) of 3.10% and 2.62% (expressed as % wet matter), respectively.

Meats are marinated mainly to provide them with odour and flavour, and make them more moist and tender, as the acid used during marination weakens muscle tissue (Lunde et al., 2008). In previous work by Egea et al. (2018) immersion marination with spices and vinegar was not sufficient to improve the toughness of entire male pork with high levels of AND. However, in the present study, the ingredients used in the marinade, mainly phosphates, and the massaging of the meat during injection may have contributed to the entire male pork obtaining similar texture scores to meat from castrated pigs, as phosphates increase the water holding capacity and reduce cooking losses, resulting in good texture of this type of meat (Warner, 2023). Wine can also have a tenderising effect on meat, as it is a proteolytic liquid that breaks protein chains, thereby promoting the reduction of toughness (Istrati et al., 2015). Both texture and flavour are determining factors that influence the preference for meat products (Felderhoff et al., 2020; Udomkun et al., 2018), hence the acceptability score (6.4 out of 9) of this strategy on entire male pork, by the consumers surveyed. However, other factors can influence the masking of boar odour found in fresh entire male pork, such as the cooking method used. High temperatures in cooking methods, such as frying, are more effective, as the compounds responsible for the boar taint (AND and SKA), being volatile, could be partially degraded during the heating process (Peñaranda et al., 2017).

Table 4 shows the responses of consumers, by sex and type of pork, to the questions asked in the questionnaire after tasting the pork samples. No significant differences ($P > 0.05$) by type of pork or sex were observed for any of the questions asked (meat samples had a strange odour/flavour, seemed too spiced or not spiced enough, and I would buy them). The frequency of "no" responses to the questionnaire questions was higher than "yes", except for purchase intention where "yes" was higher ($P \leq 0.05$). Overall, consumers gave the strategy an adequate perception to the amount of spices used. The question of whether consumers detected a strange odour/flavour (farm or animal) obtained

**Table 3**
Sensory assessment[1] of the marinated cooked castrated and entire male pork according to sex and consumers who have experienced an unpleasant odour/flavour when eating pork [mean, standard error (SE) and root-mean-square error (RMSE)].

| Type of pork | Castrated | | | | Entire male | | | | SE | RMSE |
|---|---|---|---|---|---|---|---|---|---|---|
| Sex | Woman | | Men | | Woman | | Men | | | |
| Unpleasant odour/flavour eating pork | No | Yes | No | Yes | No | Yes | No | Yes | | |
| N | 23 | 37 | 36 | 24 | 23 | 37 | 36 | 24 | | |
| Odour | 7.48[f] | 7.08[f] | 6.52[g] | 6.75[g] | 7.04 | 7.29 | 6.97 | 6.42 | 0.12 | 1.71 |
| Flavour | 7.26 | 6.73 | 6.53 | 6.79 | 6.43 | 6.86 | 6.31 | 6.71 | 0.15 | 2.43 |
| Hardness | 7.17 | 6.97 | 6.89 | 6.83 | 6.83 | 6.92 | 7.03 | 6.83 | 0.13 | 1.91 |
| Juiciness | 7.09 | 7.16 | 6.89 | 6.67 | 7.09 | 7.14 | 7.00 | 6.71 | 0.13 | 1.94 |
| Acceptability | 7.00 | 6.65 | 6.17 | 6.79 | 6.30 | 6.57 | 6.33 | 6.33 | 0.16 | 2.87 |

Values with different superscripts significantly differ at $P \leq 0.05$. a,b: effect of pork type. f,g: effect of sex. x,y: effect of consumers who have experienced an unpleasant odour/flavour when consuming pork.
[1] Scores from 1- dislike very much to 9-like very much.

**Table 4**
Classification of consumer responses to questions regarding the marinated cooked pork (frequency and percentage).

| Questions | Pork | Sex | Yes | | No | |
|---|---|---|---|---|---|---|
| | | | N | % | N | % |
| *Have you detected any strange odour/flavour such as farm/ animal?** | C | Woman | 11 | 9.2 | 49 | 40.8 |
| | | Men | 16 | 13.3 | 44 | 36.7 |
| | E | Woman | 17 | 14.2 | 43 | 35.8 |
| | | Men | 14 | 11.7 | 46 | 38.3 |
| *Does this sample seem too spiced?** | C | Woman | 16 | 13 | 44 | 37.0 |
| | | Men | 22 | 18.3 | 37 | 31.0 |
| | E | Woman | 26 | 21.7 | 34 | 28.3 |
| | | Men | 21 | 17.5 | 39 | 32.5 |
| *Do this sample not seem spiced enough to you?** | C | Woman | 9 | 7.5 | 51 | 42.5 |
| | | Men | 13 | 10.8 | 47 | 39.2 |
| | E | Woman | 7 | 5.8 | 53 | 44.2 |
| | | Men | 12 | 10.0 | 48 | 40.0 |
| *Would you buy it?** | C | Woman | 41 | 34.2 | 19 | 15.8 |
| | | Men | 36 | 30.0 | 24 | 20.0 |
| | E | Woman | 37 | 30.8 | 23 | 19.2 |
| | | Men | 35 | 29.2 | 25 | 20.8 |

Pork C: castrated male pork, E: entire male pork. *Significant differences between "yes" or "no" response in total consumers ($P \leq 0.05$), but not between pork and sex ($P > 0.05$), Chi-squared Test.

"yes" rates between 9.2%–13.3% for entire male pork, and 14.2–11.7% for castrated pork, among women and men, respectively. As for the question of whether they would buy it or not, a "yes" average of 64.2% for marinated castrated pork, and 60.0% for marinated entire male pork, was obtained, among all consumers. The same purchase intention corroborates the effectiveness of the masking strategy, as only a low percentage of consumers perceived unpleasant odours/flavours when consuming pork samples, with these consumers being sensitive to boar taint, and would therefore avoid consuming this type of pork (Borrisser-Pairó et al., 2017; Peñaranda et al., 2020).

### 3.3. Part 3: informed consumer acceptability after being informed about castration

Fig. 3A shows the mean acceptability scores provided by consumers after receiving information about the castration of male piglets. It shows that there were no significant differences ($P > 0.05$) by type of pork (castrated or entire male), or informed and uninformed consumers, obtaining an acceptability value of 6.1 for informed consumers and 6.5 for uninformed consumers, for both types of meat. This shows the effectiveness of the masking strategy. Consumer perception of fresh pork and pork products is a multidisciplinary approach in which many factors are involved, not only intrinsic product characteristics but also external to the product, such as psychosocial, ethical, animal welfare, environmental impact, and sustainability (De Araújo et al., 2022; Font-i-Furnols & Guerrero, 2022). Consumers increasingly perceive animal welfare as a positive factor when purchasing a meat product (Tomasevic et al., 2022). However, if this is detrimental to the intrinsic characteristics of the product, the sensory quality of the product takes precedence (AECOC, 2021; Font-i-Furnols et al., 2019).

In terms of purchase intention, no significant differences ($P > 0.05$) were observed by meat type or sex (Fig. 3B), with a purchase intention of 67.5% for castrated pig meat and 58.1% for injection-marinated entire male pork. These purchase intention percentages were similar to those provided by consumers before receiving information on the castration of piglets. Although animal welfare and sustainability have become a consumer priority (AECOC, 2021), and labels with specific claims and the provision of extra information have been shown to increase consumer purchase intention, it is possible that consumers do not have enough information on surgical castration without anaesthesia and its possible alternatives given by the infogram (Aluwé et al., 2022). On the other hand, the extrinsic characteristics of the product could not be not enough to improve the purchase intention. As previously mentioned, the acceptability of pork is mainly affected by sensory quality, especially the attributes of juiciness, firmness, and flavour, with the latter ones making a difference in overall acceptability (Felderhoff et al., 2020; Peñaranda et al., 2020). Furthermore, in recent years a growing consumer interest in meat products with new flavours has been observed, demonstrating that sensory characteristics define consumer acceptability (De Araújo et al., 2022).

### 3.4. Part 4: consumption habits

The results of the questions regarding consumption habits by sex are presented in Fig. 4A. Of the consumers surveyed, 50.8% stated that they have never experienced an unpleasant odour/flavour when consuming pork, showed significant differences between men and women ($P \leq 0.05$), with the latter indicating experience as being more frequent. While the vast majority of people are sensitive to the odour of skatole, a significant proportion of consumers cannot perceive the odour of androstenone, making it detectable by only part (30–40%) of the population (Font-i-Furnols, 2012). Previous studies have found a relationship between sex and sensitivity, showing that women were significantly more sensitive than men (Mörlein et al., 2013), as it has been shown that there is a genetic predisposition to be able to smell it that is related to the human olfactory receptor OR7D4 (Lunde et al., 2012; Voznessenskaya & Klyuchnikova, 2017). In contrast, the work of Borrisser-Pairó et al. (2017) and Peñaranda et al. (2020) found no significant differences between the two genders, although they did observe a tendency towards a greater sensitivity to AND in women. Consequently, consumers with AND sensitivity, especially women, will penalise the acceptability of boar-tainted pork and will therefore be more likely to reject this meat if these compounds are not to their liking (Panella-Riera et al., 2016). However, in the present work, the sensory attribute scores of entire male pork were not penalised among consumers, who tended to perceive unpleasant odour/flavours during pork consumption. Therefore,

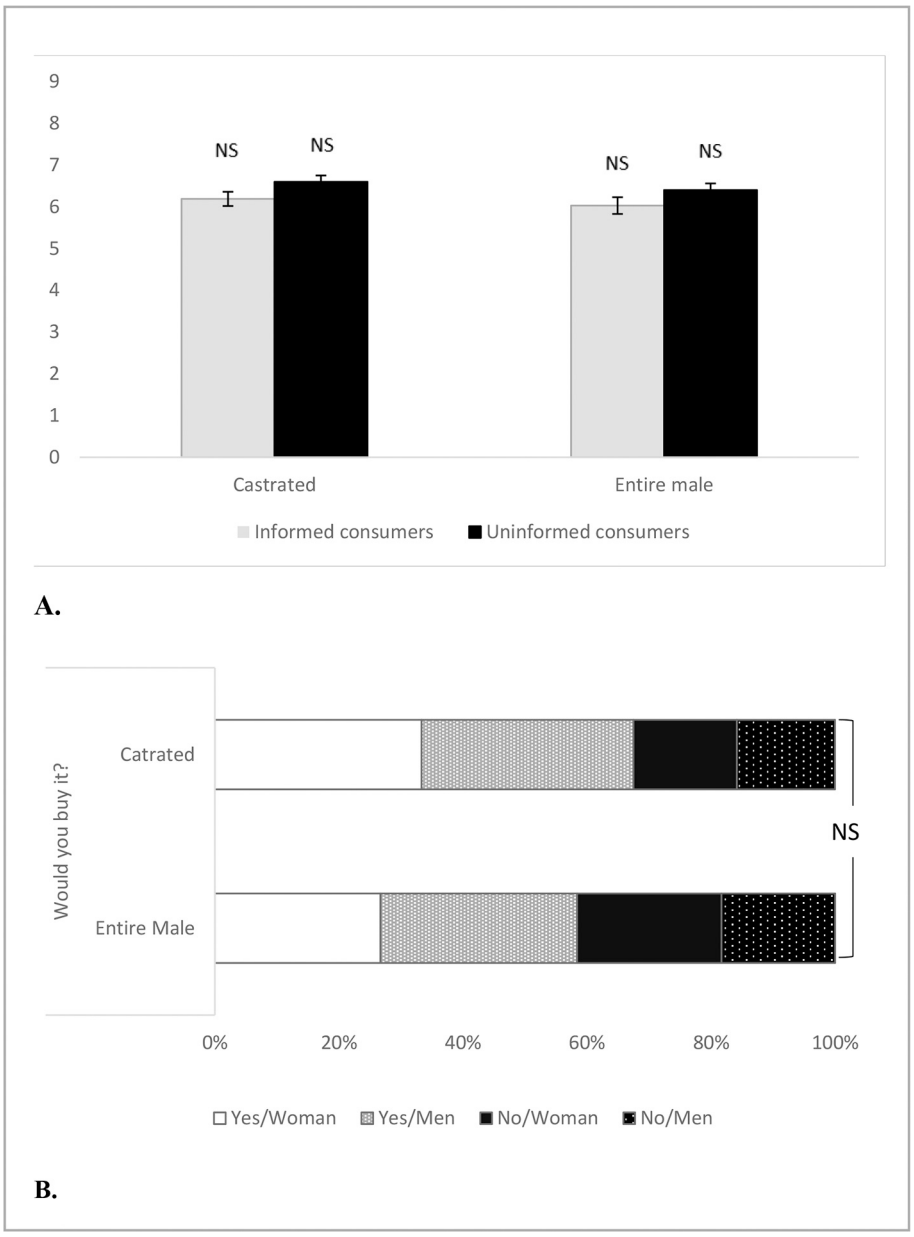


**Fig. 3.** Graphic representation. A: acceptability scores of pork from castrated and entire male injection marinated by consumers in uninformed and informed conditions (mean ± standard error, scale 1: dislike very much to 9: like very much). B: frequency of consumers' intention to buy pork (yes or no) by sex and type of pork.
Different superscripts significantly differ at $P \leq 0.05$. a,b: effect of tasters. x,y: effect of meat type.
NS: non-significant differences ($P > 0.05$).

marinating by injection seems to improve the sensory quality of entire male pork.

For the question of whether they knew that sometimes male pigs intended for consumption are castrated without anaesthesia at birth, 88% of the respondents were not aware of this issue, reflecting how most consumers do not have sufficient knowledge about pig production systems (Aluwé et al., 2020). Furthermore, 70.0% of consumers stated that they would buy castrated pork to eliminate the unpleasant odour/flavour and 60.8% would buy spiced/marinated non-castrated pork if marination eliminated the unpleasant odour/flavour, with no significant differences observed between genders ($P > 0.05$). Several studies have demonstrated a heterogeneity in consumer attitudes towards castration and its alternatives (Tomasevic et al., 2020), as consumers prefer products from animals reared under animal welfare conditions (García-Gudiño et al., 2021), but their preference will largely depend on the presence of boar taint (Font-i-Furnols et al., 2019). In this sense, Aluwé et al. (2020) observed that for consumers, the treatment of pigs during production was important, as, although they are in favour of castration for the sensory quality of the meat, they believed that it was painful for the pigs if it was not done properly.

Overall, 87.5% of consumers would be willing to pay more for a product that ensures animal welfare (Fig. 4A), indicating that they would be willing to pay 10% more, in half of the respondents (52.5%, Fig. 4B) no significant differences between genders were observed ($P > 0.05$), nor by age ranges (data not shown). As discussed, animal welfare and environmental impacts have become important drivers of consumer acceptability and purchase intention, and the consumer trend is increasingly moving towards meat products with specific claims in this regard (Ruiz-Capillas et al., 2021), but they still place more value on freshness, quality, and taste of meat (Derstappen & Christoph-Schulz,

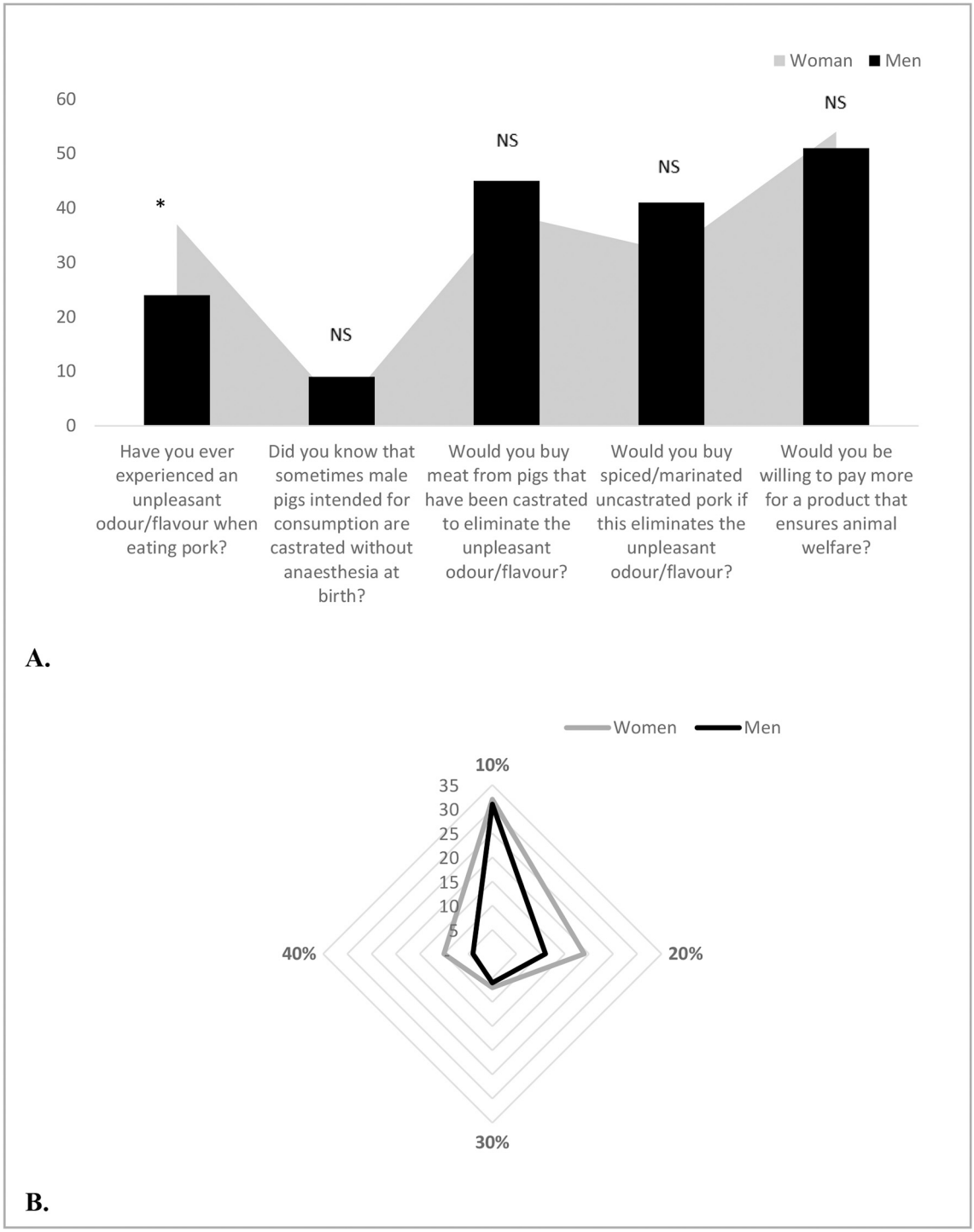


**Fig. 4.** Graphic projection. A: demographics of consumers by sex. B: how much more they would be willing to pay for this type of product if animal welfare is guaranteed.
NS: non-significant differences ($P > 0.05$), *: significant differences ($P \leq 0.05$).

2022). As for the willingness to pay more for a product that guarantees the safety and quality of the animals, several studies have concluded that this will mainly depend on the purchasing power of the consumers, regardless of age or sex (Derstappen & Christoph-Schulz, 2022; Tomasevic et al., 2022).

## 4. Conclusion

Pork injection marination is presented as a possible technological strategy for the marketing and revalorization of entire male boar tainted pork loins, as it improves the sensory quality and ensures good acceptability and purchase intention by consumers. The combined use of flavourings, wine, and phosphates allowed obtaining similar ratings by consumers between meat from castrated and entire male pork. Therefore, it contributed to a reduction in the perception of boar taint and an improvement in texture of entire male pork.

However, consumer information about entire male pork is scarce, as 88% of the respondents stated that they had no knowledge about

castration without the anaesthesia of piglets. As for animal welfare, consumers perceived it as a positive factor in buying a meat product, and would be willing to pay more for a product that guarantees animal welfare (87.5%), as long as it did not undermine its sensory quality.

It is therefore important to increase consumers' knowledge about castration and animal welfare to highlight the value of the strategies developed for entire male pork, and thus to increase their purchase intention, as consumer perceptions and attitudes in product development are key.

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## Ethical statements

1. Ethical approval for the involvement of human subjects in this study was granted by Murcia University Research Ethics Committee, Reference number ethics ID: 3566/2021, 13/10/2021. Please find attached in pdf the REPORT OF THE RESEARCH ETHICS COMMITTEE OF THE UNIVERSITY OF MURCIA.
2. Participants gave informed consent via the statement "I am aware that my responses are confidential, and I agree to participate in this survey" where an affirmative reply was required to enter the survey. They were able to withdraw from the survey at any time without giving a reason. The products tested were safe for consumption.
3. The study was explained to consumers in the questionnaire. All participants acknowledged an informed consent statement in order to participate in the study.

## CRediT authorship contribution statement

**Irene Peñaranda:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Macarena Egea:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization. **M. Belén Linares:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **M. Belén López:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Conceptualization. **M. Dolores Garrido:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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