1
2 **CONSUMERS' SENSORY ACCEPTABILITY OF PORK FROM**
3 **IMMUNOCASTRATED MALE PIGS**

4 M. Font i Furnols^{1*}, M. Gispert¹, L. Guerrero¹, A. Velarde¹, J. Tibau², J. Soler², M.
5 Hortós¹, J.A. García-Regueiro¹, J. Pérez^{3,4}, P. Suárez³, M.A. Oliver¹

6
7 ¹ IRTA, Finca Camps i Armet, 17121 Monells, Spain.

8 ² IRTA, Veïnat de Sies, 17121 Monells, Spain.

9 ³ PFIZER Pfizer Salud Animal, Avda. de Europa 20B, Parque Empresarial La Moraleja,
10 28108 Alcobendas (Madrid), Spain

11 ⁴ NUTEGA, Marconi, 9, 28820 Coslada Madrid, Spain
12

* Corresponding author: Telf.: + 34 972 63 00 52; Fax: +34 972 63 03 73; E-mail:
maria.font@irta.es (Maria Font i Furnols)

Abstract

Boar taint is the off-odour or off flavour of cooked pork. Currently, the most common method of controlling boar taint is surgical castration. However, immunocastration has been used in some parts of the world as an alternative to surgical castration. The aim of this study was to evaluate the sensory acceptability of immunocastrated pigs meat (IM) compared with meat from females (FE), surgically castrated (CM) and entire males (EM). Twenty animals of each type were evaluated by 201 consumers in 20 sessions. *Longissimus thoracis* muscle of the different animals was cooked in an oven at 180°C for 10 minutes. Consumers scored the odour and the flavour of the meat in a 9-point category scale without an intermediate level. There were no significant differences in consumer's evaluation of meat from IM, CM, and FE. In contrast, EM meat presented a higher percentage of dissatisfied scores and was significantly ($P<0.05$) less accepted than meat from CM, IM and FE. Consumers' acceptability of EM meat was always lower, independently of its androstenone levels. However meat with low levels of androstenone was more accepted than meat with medium or high levels of this substance. It can be concluded that immunocastration produced pork that was accepted by the consumers, and was comparable to pork from CM or FE.

Keywords: immunocastration, boar taint, consumers' acceptability, androstenone

1. Introduction

Boar taint is the off-odour or off flavour of pork, especially detectable upon cooking. It is due mainly to the presence of two substances, androstenone (Patterson, 1968) and skatole (Vold, 1970; Walstra & Maarse, 1970). Androstenone (α -androst-16-en-3-one)

has a urine odour and is a pheromone synthesized in the Leydig cells of the testis. Its levels depend on the age, weight, sexual maturity, feeding and rearing conditions, herds and genetics (Bonneau, Desmoulin & Dumont, 1979; FØrland, Lundström & Andresen, 1980; Claus, Weiler & Herzog, 1994; Walstra & Garssen, 1995; Squires, Lou & Gibson, 1996; Rydhmer, Zamarastkaia, Andersson, Algers & Lundström (2003); Doran, Whittington, Wood & McGivan, 2004; Aldal et al., 2005; Nicolau-Solano, McGivan, Whittington, Nieuwhof, Wood & Doran, 2006; Salmon & Edwards, 2006). Skatole (3-methyl-indole) has a faecal odour and is the product of the anaerobic degradation of tryptophan in the gut. Its levels depend on the diet, rearing conditions and handling of the pigs as well as sex, age and genetics (Lundström et al., 1988; Larsen, Hansen & Hansen-MØller, 1993; Claus et al., 1994; Friis, 1995; Hansen, Mikkelsen, Agerhem, Laue, Jensen & Jensen, 1997; Babol, Zamaratskaia, Juneja & Lundström, 2004; Lin, Lou & Squires, 2006). As androstenone is synthesized in the testis the best way to reduce/eliminate this substance is castration. Moreover castration also reduces skatole levels. Surgical castration without anaesthesia is the most common practice to avoid boar taint in the majority of the European countries. Surgical castration without anaesthesia is painful and stressful for the pigs and it is not tolerated by animal welfare organizations (EFSA, 2004; Thun, Gajewski & Janett, 2006; Prunier et al., 2006). Nowadays surgical castration without anaesthesia is forbidden in Norway and will be banned in Switzerland in 2009. Moreover surgical castration will be forbidden in Norway in 2009. Banning surgical castration is also under consideration in other European countries. A more welfare-friendly alternative to surgical castration is immunological castration (Thun et al., 2006). Switzerland is the only country in Europe where it is authorized. Immunization against gonatodrophin-releasing factor (GnRF) suppresses testicular activity. This results in reduced testicular size as well as decreased

levels androstenone. (Dunshea et al., 2001; McCauley et al., 2003; Jaros, Bürgi, Stärk, Claus, Hennessy & Thun, 2005; Evans, 2006).

The last step in the pork chain is the consumer. Boar taint affects the acceptability of pork meat by consumers. Many studies have reported on the influence of the sex of pigs and/or the levels of androstenone or skatole in the acceptability of pork by consumers. Some studies showed no differences in the acceptability of meat from entire male and female or castrates (Rhodes, 1971; 1972; Cowan & Joseph, 1981; Cliplef, Grinwich & Castell, 1984; Kempster, Dilworth, Evans & Fisher, 1986; Nold, Romans, Costello, Henson & Libal, 1997). However in other studies the acceptability differed depending on the sex of the animal and/or the levels of boar taint, androstenone or skatole (Desmoulin, Bonneau, Frouin & Bidard, 1982; Lundström, Malmfors, Fjelkner-Modig & Szatek, 1983; Walstra, Engel & Mateman, 1986; Diestre, Oliver, Gispert, Arpa & Arnau, 1990; Agerhem & Tornberg, 1994; Godt, Kristensen, Poulsen, Juhl & Bech, 1996; Siret, Béague, Fischer & Chevillon, 1997; Bañón, Andreu, Laencia & Garrido, 2004). The acceptability of the pig meat also depends on the country of assessment, the gender and age of consumers and the sensitivity of consumers to androstenone (Matthews et al., 2000; Weiler et al., 2000; Font i Furnols, 2000; Font i Furnols, Gispert, Diestre & Oliver, 2003). Regarding immunocastration, Hennessy (2006) reported higher sensory acceptability of the immunocastrated meat compared to boars to Japanese and Filipino consumers. As far as the authors are aware, no studies evaluating the sensory acceptability of meat from immunocastrated pigs in any European country have been performed. Consequently the aim of this study was to determine the Spanish consumers' sensory acceptability of pork from immunocastrated pigs compared with pork from females, surgically castrated and entire males.

2. Materials and methods

2.1. Animals

Eighty Pietrain x (Duroc x Landrace) crossbred pigs were randomly selected to supply meat for consumer testing, 20 of each type: females (FE), entire males (EM), surgically castrated (CM) and immunocastrated pigs (IM). The animals were selected from animals reared in controlled conditions at the Institute for Food and Agricultural Research and Technology (IRTA) experimental farm in Monells (Spain). Immunocastration (IMPROVAC © Pfizer Animal Health) was carried out in two 2 mL doses given subcutaneously in the neck. The first dose of 2 mL was delivered subcutaneously at 77 days of age and the second one at 146 days of age, which was approximately 4 weeks before the slaughter. Pigs were reared separately by sex. At the time of slaughter, they were anaesthetised with 85% CO₂ and slaughtered in controlled conditions at IRTA's experimental abattoir in Monells (Spain).

2.2. Sampling and sampling preparation

Approximately 24 hours after slaughter, after chilling, a piece of loin (*Longissimus thoracis* muscle) with subcutaneous fat was taken to be used in this study. The cut was obtained between the 2nd and 3th last ribs and proceeding 6 cm cranially. The loins were frozen at -20°C and retained less than 2 months during the conduct of the consumer evaluations. Preparation of the samples was similar to that reported by Mathews et al. (2000) but without precooking the meat samples. The day before the test, a loin was thawed at 4°C over 24 h. The raw loin was cut into 1.5 cm-thick slices. Each slice was

cut into 4 pieces, each 1.5 cm-thick, avoiding the extremes of the slice and trimmed to have 3 mm of the subcutaneous fat. Each piece was placed in an cylindrical aluminium foil container (72 mm of inner diameter in the bottom and 84 mm in the top and 17 mm high), covered with aluminium foil and codified with a random 3-digit code. The raw pieces within the covered aluminium containers were cooked in a pre-heated oven (FAGOR Innovation Class A) at 180°C for 10 minutes.

In addition, androstenone and skatole levels were measured in the subcutaneous fat following the methodology described by García-Regueiro and Rius (1998) and Rius, Hortós and García-Regueiro (2005).

2.3. Experimental design

The consumer study was carried out in one location, Monells (Girona), in the North East of Spain, at IRTA's Sensory Laboratory. Two hundred and one consumers were selected randomly but with quotas for gender (51.7% men and 48.3% women) and age (from 18 to 77 years) following the Spanish age distribution. There was no pre-selection of consumers based on the ability to detect boar-taint. Table 1 shows the characteristics of the consumers who participated in the study.

Twenty sessions of 10 different consumers each were carried out (one session had 11 consumers). In each session every consumer evaluated 4 samples - one from each type of animal. Consequently, meat from 80 animals was evaluated. Samples were served in a monadic way, one every 3 minutes, to the consumers and in a different order following a design that avoided the first sample and carry-over effect (MacFie, Bratchell, Greenhoff & Vallis, 1989).

Consumers were only informed that they would evaluate 4 different pork samples and how they should do it. They were instructed to smell the meat immediately after opening the sealed aluminium container and to evaluate odour acceptability. They were then requested to taste the meat sample and evaluate its flavour acceptability. They were asked to eat unsalted toasted bread and rinse their mouth with water before evaluate each sample, including before the first one.

2.4. Questionnaire

Consumers were asked to score each sample for odour and flavour on a modified 9-point category scale: ‘dislike extremely (1), ‘dislike very much’ (2), ‘dislike moderately’ (3), ‘dislike slightly’ (4), ‘like slightly’ (6), ‘like moderately’ (7), ‘like very much’ (8) and ‘like extremely’ (9). The medium level ‘neither like nor dislike’ (5) was not included to stimulate consumers to commit themselves and not to allow the easiest response (Guerrero, 1999). For calculations, the hedonic scale was considered as quantitative (from 1 to 9) and number 5 was omitted. This was done because the distance between each category of the scale should be the same (Amerine, Pangborn & Roessler, 1965) and it was considered that the distance between ‘dislike slightly’ and ‘like slightly’ was the double than between the other contiguous categories.

2.5. Statistical analysis

Frequency of scores for each type of animal were obtained depending on their rating level, and were grouped in 4 categories: dislike a lot (includes ‘dislike extremely’ and ‘dislike very much’), dislike (includes ‘dislike moderately’ and ‘dislike slightly’), like

(includes 'like slightly' and 'like moderately') and like a lot (includes 'like very much' and 'like extremely'). Comparison between frequencies obtained for each type of animal, two by two, within each rating group was performed using the Chi-squared test. The MIXED procedure of SAS (SAS Institute Inc., Cary, NC, USA) was used to determine whether significant differences between the different type of animals existed. The model included type of animal as fixed effect, tasting session as blocking effect and consumer as random effect. Meat samples were also classified depending on their androstenone levels as low (less than 0.5 µg/g), medium (0.5 µg/g to 0.99 µg/g) and high (more than 0.99 µg/g). The MIXED procedure was also used to determine differences of odour and flavour acceptability depending on the androstenone level classification. In this case androstenone classification was included as fixed effect. In both cases, differences between least square means were obtained after applying Tukey test. There was not sufficient variation in the skatole levels to allow a meaningful analysis.

3. Results and discussion

There were no significant differences in the frequency of categories of consumer scores (dislike a lot; dislike; like; and like a lot) for either odour or flavour for the IM pigs compared to either the CM or the FE pigs (Table 2). In contrast, frequency of 'dislike' and 'dislike a lot' scores obtained for the acceptability of the odour of EM meat were significantly higher than those obtained for meat from FE, CM and IM pigs (Table 2). The frequency of 'like' scores was significantly lower for meat from EM than for the other type of animals. 'Like a lot' scores was numerically lower for EM meat compared to the other types of meat, but was not significant ($P>0.05$). These results indicate that

the odour of meat from EM was less acceptable to consumers than was the odour of meat from FE, CM and IM pigs. Similar results were obtained for the flavour scores. 'Dislike a lot' scores were significantly higher for meat of EM than for other types of meat. The frequency of 'dislike' scores was significantly higher for EM compared to CM and IM animals and was numerically higher, but not significantly different ($P>0.05$) from FE. The meat from EM also had lower 'like a lot' scores, which were not significantly lower than meat from FE, but were significantly lower than CM and IM. There were no significant differences in the 'like' category among the four types of pigs. Looking at the frequency of scores it can be seen that there are differences among type of meat and between odour and flavour. These differences in consumer's response for odour and flavour may be explained by the effect of the temperature at which samples were assessed. Androstenone is a volatile compound and it is better perceived at high temperature (Agerhem and Tornberg, 1995).

The percentage of dissatisfied ('dislike a lot' and 'dislike') odour scores given to EM (41%) were the double than those given to FE (20%), IM (20.1%) and CM (21%). Matthews et al., (2000) reported 34 % of dissatisfied odour scores in EM and 28 % in FE. When the flavour is considered, the difference in the percentage of dissatisfied scores between FE (21.5%) and EM (33.3%) was lower. This difference was higher between IM and CM pigs with respect to EM (14.5 and 12.1 vs. 33.3%). These percentages are higher than those reported by Mathews et al. (2000) where the flavour percentage of 'dissatisfied' scores was 22 % for EM and 19 % for FE. These differences could be due to the cooking methodology used in both studies. Matthews et al. (2000) cooked and reheated the loins before serving them to the consumers. In the present study loins were cooked just before serving them. The excess of cooking in Matthews et

al. (2000) study could result in underestimating the perception of boar taint (as suggested by the same authors), which would result in a decrease in the percentage of 'dissatisfied' scores given to the EM pigs and decrease in the difference of 'dissatisfied' percentages between EM and FE (6% for odour and 3% for flavour in the study from Matthews et al. (2000) versus 20% for odour and 12% for flavour in the present study). A portion of the differences could also be due to the omission of the intermediate level 'neither like nor dislike' of the scale in the present study.

When considering the mean of the consumers' scores for acceptability of odour and flavour of all the animals evaluated, the meat from EM was scored significantly ($P<0.05$) lower than acceptability of meat from CM, IM and FE (Table 3). Moreover consumers did not differentiate between pork from FE, CM and IM pigs. This outcome shows that meat from CM and IM was not distinguishable by consumers, based on these sensory evaluations. This is in accordance with those results obtained for Japanese and Filipino origin consumers (Hennessy, 2006). Lagerkvist, Carlsson and Viske (2006) carried out a Choice Experiment and concluded that, for Swedish consumers, immunocastration is a socially viable alternative to surgical castration. However further studies are needed to know the opinion of the rest of the European consumers. If this is favourable, immunocastration can be a good alternative to surgical castration production since it reduces androstenone level and increases the yield of lean (Jaros et al., 2005; Evans, 2006). Moreover, in agreement with the results of our study the meat obtained has good taste quality, at the same level than CM and FE.

Although consumers scores were significantly lower for the odour and flavour of meat from EM than the other type of meats studied, flavour scores tended to be higher than odour scores. This is in accordance with other works (Desmoulin & Bonneau, 1981; Lundström et al., 1983; Walstra et al., 1986; Diestre et al., 1990; Matthews et al., 2000)

and can be explained by the fact that although androstenone and skatole are not highly volatile (García-Regueiro, Rius & Díaz, 1995) part of these substances volatilize during the cooking and can be perceived better in warm meat. Moreover, boar taint is perceived mainly in the odour during the cooking (Claus, Schopper, Wagner & Weiler, 1985; Denhard, Claus, Herbert & Hillenbrand, 1995).

Differences in the consumer acceptability of pork depending on the sex of the pig has been reported in other studies: FE or CM pigs are perceived to have less boar taint than EM (Desmoulin et al., 1982; Agerhem et al., 1994; Matthews et al., 2000; Bañón et al., 2004). Bonneau et al. (2000) reported that with the pig population currently raised in Europe, which includes boars with different androstenone levels (Walstra et al., 1999), consumers would be less satisfied with meat from EM than from FE. Nevertheless, in other studies consumers did not find differences between EM and FE or CM meat (Rhodes, 1971; 1972; Cowan et al., 1981; Kempster et al., 1986; Nold et al., 1997). These differences between studies can be due to different cooking and evaluation methodology as previously discussed (Siret et al., 1997; Nute, Whittington, Warriss & Wood, 1995; Wood, Nute, Fursey & Cuthbertson, 1995; Agerhem & Tornberg, 1995) as well as intrinsic differences in the perception of boar taint by the consumers depending on their origin, age, sex or androstenone sensitivity (Matthews et al., 2000; Weiler et al., 2000; Font i Furnols et al., 2003), or even differences in the breeds, ages of slaughter or rearing conditions of animals at slaughter.

In this study, when meat samples from EM, which had high levels of androstenone ($>0.99 \mu\text{g/g}$), were kept out of the analysis there were still significant differences between sexes (Table 3). Odour and flavour scores of meat from EM with levels of androstenone $<1 \mu\text{g/g}$ (i.e. low or medium levels) were still significantly ($P<0.05$) lower than those from FE, CM or IM. This indicates that the selection of meat from boars with

low or medium levels of androstenone would not solve the problem of boar taint and they will be still less accepted by consumers than meat from FE or castrated (surgically or immunologically) animals. These results were different from those reported by Font i Furnols (2000) where consumers from 7 EU countries as a pool did not differentiate between FE and EM with low or medium androstenone levels. Moreover, as commented before, in that work meat was cooked and reheated and an important part of the off-flavours might have disappeared.

When only samples from EM with low ($<0.5 \mu\text{g/g}$) or none androstenone content were considered, EM meat presented numerically lower odour scores than CM, IM and FE but these were not significantly lower (Table 3). Flavour scores of EM meat with low androstenone content were significantly ($P<0.05$) lower than those from CM and IM pigs but not from FE. Flavour scores were higher than odour ones and the differences in acceptability of the different type of animals was clearer for flavour than for odour. This may be due to the fact that, although consumers were asked to evaluate the odour immediately after open the container, in some cases they waited more than recommended and part of the odour was gone. These results shows that the selection of boar meat with low androstenone content is not enough to ensure the acceptability of pork at the same level as meat from CM or FE. Desmoulin et al. (1982) also found that roasts and cutlets from EM were always scored lower than the other type of meats, even if the androstenone content was low. However, Lundström et al. (1983) found, that, on average, if a trained panel classified meat from EM as free of boar taint, then the acceptability of that meat for consumers was similar to meat from FE.

All the samples used in this study with low androstenone levels had also low skatole levels. So, it is unlikely that skatole would have influenced the acceptability of the meat by the consumers. Only one EM animal presented skatole levels higher than $0.10 \mu\text{g/g}$

and it also presented high androstenone levels. This result suggests that other compounds also affect consumers' acceptance of pork from EM.

In this study, we did not take into account androstenone sensitivity of the consumers. All the consumers were considered together because our objective was that they match the population in order to be able to generalize the results obtained. The results are interesting in that all the consumers, as a pool (sensitive and insensitive to androstenone), found that the odour and flavour of meat (across all pig types) with low androstenone content was significantly ($P<0.05$) more acceptable than the odour and flavour of the pork with medium or high androstenone levels (Table 4). Weiler et al. (2000) found similar results for the odour scores evaluated by Spanish sensitive consumers to androstenone. However for less sensitive or insensitive Spanish consumers' odour acceptability was not affected by the content of androstenone. Flavour scores were not affected by androstenone content, independently of the sensitivity of the consumers. The same study also reported that German consumers, sensitive to androstenone, did not score odour differently depending on the androstenone content but did score flavour of meat with low androstenone content significantly higher (more acceptable) than flavour of meat with high androstenone content. Again, the different cooking methodology could explain partly the differences observed between different studies. Desmoulin et al. (1982) only found slight ($P<0.10$) differences in the percentage of unfavourable opinions on odour when androstenone level was high compared to medium and low androstenone. Moreover, loin, belly and cured ham from EM with high androstenone levels ($>1 \mu\text{g/g}$) were less accepted than from CM by Spanish consumers (Diestre et al., 1990). These consumers did not find differences in acceptability between cooked hams from EM and CM.

4. Conclusions and implications

Spanish consumers were not able to differentiate, based on odour and flavour, between cooked meat from immunocastrated pigs, surgically castrated pigs and female pigs. The consumer's acceptability of pork meat was related to the level of androstenone, with lower androstenone concentrations being the most accepted. However entire male pork was always less accepted by consumers, independently of its androstenone content, indicating the influence of factors other than androstenone. Furthermore, this suggests that measuring androstenone content of entire male pigs may not adequately screen out unacceptable meat. Further studies will be needed to understand the sensory acceptability of meat from immunocastrated pigs by consumers from other EU countries. Moreover it will be important to understand consumers' attitudes and acceptance of immunocastration as an alternative to surgical castration in pigs.

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529

530 Table 1: Characteristics (age and gender) of the consumers.

531

	Total	Men	Women
Age (%)			
18-25 years	16.9	19.2	14.4
16-40 years	32.8	33.7	32.0
41-60 years	32.8	30.8	35.1
61-77 years	17.4	16.4	18.6
Total (%)	100.0	51.7	48.3
Total (n)	201	104	97

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535 Table 2: Frequency (%) of scores obtained depending on the animal type⁺

	CM	IM	EM	FE
<i>Odour</i> ¹				
Dislike a lot	2.0 ^b	2.0 ^b	8.0 ^a	0.5 ^b
Dislike	19.0 ^b	18.1 ^b	33.0 ^a	19.5 ^b
Like	62.0 ^a	62.8 ^a	45.5 ^b	62.5 ^a
Like a lot	17.0	17.1	13.5	17.5
<i>Flavour</i> ¹				
Dislike a lot	1.0 ^b	0.5 ^b	5.0 ^a	0.0 ^b
Dislike	11.1 ^c	14.0 ^{bc}	28.3 ^a	21.5 ^{ab}
Like	67.8	65.0	56.1	62.5
Like a lot	20.1 ^a	20.5 ^a	10.6 ^b	16.0 ^{ab}
CM: Castrated, IM: Immunocastrated, EM: Entire males, FE: Female				

⁺ Different superscripts within rows indicate significant differences (P<0.05)

¹ 'dislike a lot' includes 'dislike extremely' and 'dislike very much'; 'dislike' includes 'dislike moderately' and 'dislike slightly'; 'like' includes 'like slightly' and 'like moderately'; 'like a lot' includes 'like very much' and 'like extremely'

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Table 3: Least squared means and standard error (S.E.) of the consumers' odour and flavour scores depending on animal type ⁺

	N	CM	IM	EM	FE	S.E.
<i>All the animals</i>						
Odour	201	6.2 ^a	6.2 ^a	5.4 ^b	6.2 ^a	0.11
x Flavour	201	6.4 ^a	6.4 ^a	5.7 ^b	6.2 ^a	0.10
<i>Only EM with less than 1 µg/g of androstenone</i>						
Odour	201 ¹	6.2 ^a	6.2 ^a	5.5 ^b	6.2 ^a	0.11-0.12
Flavour	201 ¹	6.4 ^a	6.4 ^a	5.8 ^b	6.2 ^a	0.10-0.11
<i>Only EM with less than 0.5 µg/g of androstenone</i>						
Odour	201 ²	6.2	6.2	5.8	6.2	0.10-0.16
Flavour	201 ²	6.4 ^a	6.4 ^a	5.9 ^b	6.2 ^{ab}	0.10-0.15

CM: Castrated, IM: Immunocastrated, EM: Entire males, FE: Gilts

N: Number of consumers; ¹ N=171 for EM samples ; ² N=82 for EM samples

⁺ Different superscripts within rows indicate significant differences (P<0.05)

Table 4: Least squared means (LSM) and standard error (SE) of the odour and flavour consumer scores depending on the androstenone level of the meat.

	N	LSM ⁺	SE
ODOUR			
Low ¹ (<0.5 µg/g)	683	6.2 ^a	0.09
Medium (0.5 µg/g to 0.99 µg/g)	90	5.1 ^b	0.16
High (> 0.99 µg/g)	30	4.9 ^b	0.26
FLAVOUR			
Low ¹ (<0.5 µg/g)	682	6.3 ^a	0.08
Medium (0.5 µg/g to 0.99 µg/g)	87	5.5 ^b	0.15
High (> 0.99 µg/g)	30	5.3 ^b	0.25

¹ It includes entire males with less than 0.5 µg/g of androstenone, gilts, castrated and immunocastrated.

N: Number of scores given by the consumers

+ Different superscripts within column and trait indicate significant differences (p<0.05)