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Article

Effect of sex on meat quality traits and sensory properties in Argentine crossbred pigs

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Abstract:

The objective of this study was to evaluate the effect of sex on final live weight, carcass characteristics meat quality traits and sensory properties of a specific cross breed pig line (Landrace 75% x Yorkshire 25% "Degesa"). Eight randomly selected barrows (CM) and eight gilts (F) were used in the present study. No differences ($P>0.05$) between sexes for carcass characteristics, shear-force value or sarcomere length were observed. However, back fat thickness, pH@45, pH@24, water-holding capacity, marbling score and intramuscular fat content were higher ($P>0.05$) in CM than in F. Meat from CM had lower ($P=0.04$) lightness than F but similar ($P\geq0.34$) redness and yellowness. Total saturated fatty acids (SFA) proportion as well as individual SFAs (C16:0 and C18:0) were greater in CM than in F, but n-6:n-3 ratio was lower in males than females. In general, meat from males were better scored than meat from females by the trained panel in flavor attributes but the result was opposed when textural properties were evaluated. In addition, greater overall color score as well as flavor attributes were positively associated with intramuscular fat content and rate of monounsaturated FA but negatively associated with rate polyunsaturated FA proportion. In conclusion, results suggest that pork quality from Degesa crossbred pigs showed marked sex-related differences and therefore, it could be deferentially commercially by sex in the meat market.

Keywords: Fatty acids, Intramuscular fat, Meat color, Sarcomere length, Sensory panel, Shear force.

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Introduction

Argentina has been traditionally recognized as an important producer and consumer of meat from beef cattle. However, in the last past years the pork industry has been growing, leading to a greater local *per capita* consumption of meat (from 8.5 kg in 2011 to approximately 16 kg in 2020[1]. Although meat quality is a critical issue for the meat industry, Argentinian pork classification system is based only on the proportion (%) of lean tissue and on carcass yield (kg) (Resolution S.A.G. and P. No. 57/95).

The main sensory attributes defining pork quality are color, tenderness, juiciness, odor and flavor[2]. Productive managements such as diet and feeding practices[3] can affect these attributes. In addition, intrinsic aspects such as, breed, weight and sex are important[4,5,6]. Several studies[7,8,9] suggested that carcass and pork quality traits could be highly dependent on animal sex including type of castration. However, these studies obtained inconsistent results since different swine genetics lines were evaluated. This suggest that differences in meat pork quality traits related to sex are highly dependent on the breed and/or genetic hybrid considered[6].

Despite pig sex plays a key role in meat quality aspects, Argentine pig carcasses are currently commercialized as a single category "*capon*" including whole entire or castrated males and females whereas there are not researches to the current knowledge evaluating meat quality aspect of swine hybrid line (Landrace 75% x Yorkshire 25%). Therefore, the present study represents a novel approach to evaluate the effect of sex of females and castrated males' pigs on carcass and meat quality traits of swine hybrid line (Landrace 75% x Yorkshire 25% "Degesa")

Material and methods

Animal management, carcass measurements and sample collection

The trial was carried out in La Isla, Cerrillos, province of Salta (24°52'46"S, 65°24'20"W, 1,217 m altitude) Argentina, under good manufacturing practices management and welfare standards in accordance with Argentine national recommendations for animal handling. The procedure was approved by the institutional ethical and technical committee of the Catholic University of Salta (RR N° 1294/15).

Sixteen (16) crossbred pigs Degesa (Yorkshire 25% x Landrace 75%) were randomly selected from the same herd: eight females and eight males. Males were surgically castrated (CM) and females (F) remained entire. Each group was assigned to separate pens, with an area of 1.2 m^2 per animal. Animals were fed *ad libitum* with the same commercial feed and water using a hopper system. All animals were slaughtered on the same day in a commercial slaughterhouse, located 30 km from the experimental farm. At slaughter, animals were 25 wk of age and their average live weight was 125 ± 5 kg.

Individual pre-slaughter weight (PSW) and hot carcass weight (HCW) were recorded in the slaughterhouse. Muscle pH was determined 45 min (pH@45) and 24 h post-slaughter

(pH@24) on the *Longissimus lumborum* (LL) muscle, between the 12th and 13th ribs of each right half carcass. Back fat thickness was measured with a manual caliper (Starrett ®, Athol, Massachussetts, USA) and the Loin eye area (LEA) was traced and determined with ImageJ® software at the level of the 11th rib (BFT; cm) on the left carcass side. Marbling score was determined on the same rib through the Official Marbling Quality Standard score cards (Official Color and Marbling Quality Standards, Pork checkoff, USA). *Longissimus lumborum* (LL) sections between 9th and 13th ribs from each left and right carcass were cut into steaks, perpendicular to the longitudinal axis of the LL muscle. A 2.5-cm thick steak of the LL muscle was obtained from the 12–13th rib section (from cranial to caudal), of the left carcasses for proximate analysis. For this analysis, all external fat and connective tissues were previously removed. An additional 0.5-cm thick steak was obtained from the 12–13th ribs section and stored for further determination of sarcomere length. The LL muscle from the 9–11th rib section was cut into 2.5-cm thick steaks to evaluate color, warner–bratzler shear force (WBSF) and cooking loss. After 24 h of slaughter, meat samples were vacuum-packed and stored at -20 °C, until further analysis at the meat quality laboratory of EEA INTA Balcarce, Argentina. Sensory analyses were performed at the Laboratory of Sensory Analysis of the Faculty of Agronomy, National University of Buenos Aires, Argentina.

Meat quality measurements

Proximate analysis

Dry matter content was calculated as the difference between initial (fresh meat) and final weight after drying the meat for 48 h at 60 °C, in duplicate. Total lipid content was determined using an automatic extraction system (Ankom xt10, Ankon, Macedon NY, USA).

Meat color evaluation

Instrumental color was recorded using a Minolta chromameter (CR-310; Minolta Inc., Osaka, Japan) with a 50-mm-diameter measurement area using a D65 illuminant, calibrated against a white ceramic disk provided by the manufacturer. Color readings were determined 24 h *post mortem* on the exposed cross-sections of the 12th rib of the LL muscle from the left carcass. The meat sample was bloomed at room temperature for 30 min before color measurement. Each sample was measured six times and the value is expressed as an average. The system used was the CIE Lab, which provides three-color components: L* (lightness,

0 = black, 100= white), a* (red index, -a*= green, +a*= red) and b* (yellow index, -b= blue, +b= yellow).

Warner-Bratzler shear force and cooking loss

WBSF procedure was conducted according to AMSA (1995)[10] guidelines. Frozen samples (steaks of 2.5 cm of thickness) were thawed at 4 °C for 12 h, weighed and cooked on open heart electric grill (Farberware, Bronks NY). During cooking, steaks were flipped at 35.5 °C at the geometric center and grilled until temperature reached 71 °C. Internal temperature was controlled using a multi-scan digital thermometer (Scanning Thermometer, Digi-Sense, Cole Palmer). The cooked samples were chilled at 4 °C for 20 min and weighed again. Cooking loss was calculated as follows: cooking loss (%)= (weight of uncooked sample – weight of cooked sample)/(weight of uncooked sample) × 100. Chops were cooled at room temperature; six 1.27-cm diameter cores were removed parallel to the muscle fiber, and cores were sheared perpendicular to the fiber longitudinal axis. Peak shear force was measured using a digital force gauge (BFG500N, Quantro l TM, Dillon/ Quality Plus, Inc., Kansas City, MO, USA), equipped with a WBSF attachment at a cross head speed of 200 mm/min (Warner–Bratzler meat shear, G-R Manufacturing CO., Manhattan, KS, US).

Sarcomere length

Sarcomere length (SL) was determined in LL muscle samples, using a helium-neon laser diffraction method (CVI Melles Gliot. Series 7822 FH-1)[11]. Twenty (20) myofibril fragments of each sample were measured to determine the average sarcomere length.

Fatty acid profile

Fatty acid methyl esters in lyophilized LL muscle samples were obtained by direct transmethylation[12]. Fatty acid methyl esters were analyzed with a Clarus 500 (Perking Elmer) gas chromatograph provided with a capillary column CP-Select CB for FAME fused silica WCOT 100 m_0.25 mm (Cat.no.CP7420; Varian Inc.). Individual fatty acids were identified by comparing retention times with standards (Sigma, St. Louis, MO; Supelco, Bellefonte, PA; Matreya, Pleasant Gap, PA). Fatty acids were quantified by incorporating methyl tricosanoic acid (C23:0) as an internal standard, in each sample during methylation.

Sensory analysis

Twenty-four (24) hours before the sensory analysis, samples were thawed at 2.5 ± 0.5 °C at the Laboratory of Sensory Analysis of the School of Agronomy of the National University of Buenos Aires, Argentina. Loin samples (2.5 cm thick) were cooked in a double contact grill until the internal temperature reached 71 ± 1 ºC. Samples were analyzed by an analytical panel of six trained members according to international standards and meat[13-16] experience in sensory analysis. Each panelist received the samples (cubes: 1x1x2.54 cm) in Petri dishes with a three-digit randomized code. Steak samples were evaluated for the following sensory attributes: overall color (OC); odor intensity (OI); flavor persistence (FP), flavor characteristic (FC); firmness (F) and hardness (H). Panelists scored the samples using an unstructured linear 10-cm scale, where each end point corresponded to low or high score of each attribute, i.e.: OC: light pink to dark red, OI: not intense to extremely strong, FP: not persistent to extremely persistent, FC: none to strong off-flavor, F: extremely soft to hard, H: very tender to very hard (lower limit: 0 to upper limit: 10)[10].

Statistical analysis

The analysis was performed using a completely randomized design. The effect of sex on meat quality parameters was analyzed using a T test. Each animal was considered an experimental unit. The differences were considered significant at $P \leq 0.05$ and trends were considered when $P \leq 0.10$. The degree of association between physicochemical and sensory data was assessed using Pearson's correlations (significant at $P \leq 0.05$; trends $P \leq 0.10$). The statistical analysis was performed using the rcmdr package of the R core team statistical program (2013).

Results

Carcass characteristics and meat quality traits

Sex did not affect to PSW, HCW, carcass yield or LEA (P=0.48, P=0.20, P=0.22 and P=0.61, respectively; Table 1). Back fat thickness was 19 % higher (P<0.001) in CM than in F. Meat from CM tended (P=0.07) to have higher pH@45 than meat from F and, at 24 h *post mortem*, muscle pH was higher (P=0.03) in CM than in F.

No differences (P≥0.34) were observed for redness (a*) or yellowness (b*) parameters in loin samples, except for L* in F, which was 7 % higher (*P*=0.04) than in CM. In addition, shear force and sarcomere length did not differ (*P*>0.05) between meat from F and CM. No differences (*P*=0.55) in cooking loss were observed between sexes. Meat from CM had higher (*P*=0.03) marbling score and intramuscular fat content than meat of F.

Table 1: Effect of sex on live weight, carcass characteristics and meat quality

	CM	**F**	**SEM**	***P*-value**
Pre-slaughter weight, kg	124.50	121.50	7.52	0.48
Hot carcass weight, kg	101.60	98.00	5.78	0.22
Carcass yield, %	81.80	80.70	1.82	0.20
Backfat thickness, mm	25.90	21.06	3.14	<0.001
Loin eye area, cm^2	36.16	36.98	3.11	0.61
Warner bratzler shear force, N	36.00	31.00	0.86	0.26
Sarcomere length, µm	2.04	2.01	0.05	0.22
Marbling	2.60	1.70	0.83	0.03
Intramuscular fat, %	3.48	2.60	0.79	0.02
Cooking loss, %	25.52	26.74	0.96	0.55
pH@45	5.67	5.43	0.06	0.03
pH@24	5.41	5.23	0.05	0.07
	Color			
L*	52.44	56.13	3.60	0.04
a*	5.10	4.57	1.49	0.34
b*	14.56	15.16	2.16	0.94

CM= castrated male; F= female; SEM= standard error of the mean; PSE= pre-slaughter weight; HCW= hot carcass weight; CY= carcass yield; BFT= back fat thickness; LEA= loin eye area; WBSF= warner bratzler shear force; SL= sarcomere length ; MAR= marbling; CL= cooking loss; IMF= intramuscular fat; pH@45= pH of the *Longissimus lumborum* muscle at 45 min *post mortem*; pH@24= pH of the *Longissimus lumborum* muscle at 24 h *post mortem;* L* (lightness), a* (red index) and b* (yellow index).

Fatty acid profile

Total saturated fatty acid (SFA) proportion was higher (*P*<0.01) in CM than in F (Table 2); individual SFA was also higher in CM than F, with C16:0 and C18:0 ratios higher in CM than F, respectively (*P*≤0.04). The C22:5 ratio was higher (*P*<0.05) in F than in CM. No differences (*P*>0.10) were found between sexes for the remaining measurements.

Table 2: Effect of sex on fatty acids composition from the *Longissimus lumborum* (%)

Fatty acids	**CM**	**F**	**SEM**	***P*-value**
SFA	37.90	36.46	0.27	<0.01
C12:0	0.10	0.09	0.01	0.19
C14:0	1.34	1.31	0.01	0.29
C16:0	23.20	22.44	0.17	0.02
C18:0	11.91	11.19	0.17	0.04
MUFA	40.03	39.97	0.47	0.95
C16:1 cis 9	2.65	2.70	0.08	0.79
C18:1 *cis*-9	33.94	33.63	0.37	0.69
C18:1 *cis*-11	2.87	3.03	0.06	0.22
PUFA	18.99	20.15	0.54	0.29
C18:2 n-6	15.01	15.77	0.43	0.39
C18:3 n-3	1.24	1.21	0.03	0.76
C20:4 n-6	2.06	2.35	0.08	0.08
C20:4 n-3	0.03	0.04	0.01	0.21
C20:5 n-3	0.10	0.11	0.01	0.37
C22:5 n-3	0.34	0.39	0.01	0.03
PUFA n-6	17.07	18.12	0.49	0.29
PUFA n-3	1.82	1.88	0.04	0.57
		Ratios		
n-6:n-3	9.33	9.64	0.06	0.12
PUFA:SFA	0.50	0.55	0.09	0.38
MUFA:SFA	1.04	1.09	0.07	0.19

CM= castrated male; F= female; SEM= standard error of the mean; SFA (saturated fatty acids)= C12:0+ C14:0+ C16:0+ C18:0; MUFA (monounsaturated fatty acids)= C14:1 cis-9 + C16:1 cis-9 + C18:1 cis-9 + C18:1 cis-11 ; PUFA (polyunsaturated fatty acids)= C18:2 n-6 + C18:3 n-3 + C18:4 n-3 + C20:4 n-6 + C20:4 n-3 + C20:5 n-3 + C22:5 n-3 + C22:6 n-3; PUFA n-6: C18:2 n-6 + C20:4 n-6; PUFA n-3: C18:3 n-3 + C18:4 n-3 + C20:4 n-3 + C20:5 n-3 + C22:5 n-3 + C22:6 n-3.

Sensory characteristics

Sensory attributes in meat were influenced by the sex of animals. Meat from CM had higher score of flavor persistence ($P<0.01$) and tended to have higher overall color (OC, $P<0.09$) and flavor characteristic (FC; $P=0.06$) than meat from F. Hardness (H) and firmness (FI) were higher in F ($P< 0.05$). There were no significant differences in the remaining attributes ($P>0.10$; Table 3).

Table 3: Effect of sex on variability of visual, olfatory-gustatory, textural sensory variables in trained sensory panel

Attributes	Descriptors	CM	F	SEM	*P*-value
Visual	OC	6.01	5.53	0.15	0.09
Olfatory-gustatory	FC	6.39	5.84	0.11	0.06
	FP	6.70	5.63	0.13	0.001
Textural	H	4.19	4.89	0.14	0.01
	FI	3.92	4.72	0.16	0.01

CM= castrated male; F= female; SEM= standard error of the mean; OC= overall color; FC= flavor characteristic; FP= flavor persistence; H= hardness; FI= firmness.

Association between variables

Table 4 shows the correlation between physicochemical and sensory variables. Overall color grade (OC) of steaks was positively correlated with marbling score, intramuscular fat content and total MUFA proportion (r= 0.61, $P<0.01$; r= 0.52, $P<0.05$; r= 0.84, $P< 0.001$), but negatively associated with total PUFA proportion and PUFA: SFA ratio ($r\geq 0.83$; $P<0.001$). Meat hardness (H) was negatively correlated with pH24 (r= -0.46, $P<0.05$) and with marbling score (r= -0.63, $P<0.001$), but positively correlated with PUFA: SFA (r= 0.43, $P<0.05$). Overall firmness score (F) was negatively correlated with pH45 (r= -0.54, $P<0.05$), pH24 (r= -0.42, $P<0.1$), marbling score (r= -0.49, $P<0.05$), and cooking loss (r= -0.35, $P<0.05$). FC was positively correlated with intramuscular fat content (r= 0.45; $P<0.10$) and total MUFA proportion (r= 0.54; $P<0.05$), but negatively associated with total PUFA proportion (r= -0.45; $P<0.10$). Persistence (FP) showed a positive correlation with BFT, intramuscular fat content ($P<0.01$) and MUFA proportion ($P<0.05$), and a weak negative correlation with PUFA proportion and PUFA: SFA ratio ($P<0.1$). The remaining associations were not significant ($P>0.05$).

Table 4: Pearson correlation coefficient between physicochemical and sensory variables

	OC	H	FI	FC	FP
pH@45	0.03	-0.26	-0.54*	-0.27	0.06
pH@24	0.03	-0.46*	-0.42^{t}	-0.14	0.09
BFT	0.23	-0.37	-0.24	0.08	0.41^{t}
MAR	0.61**	-0.63***	-0.49*	0.25	0.29
WBSF	0.02	0.12	-0.10	0.32	0.12
SL	0.30	-0.13	-0.16	0.09	0.52*
CL (%)	-0.04	0.38	-0.35*	0.11	-0.26
IMF	0.52*	-0.46^{t}	-0.28	0.45^{t}	0.57**
MUFA	0.84***	-0.41^{t}	0.20	0.54*	0.48*
PUFA	-0.83***	0.45^{t}	-0.18	-0.45^{t}	-0.45^{t}
PUFA:SFA	-0.80***	0.43*	0.18	-0.01	-0.46^{t}

OC= overall color; H= hardness; FI= firmness; FC= flavor characteristic; FP= flavor persistence; pH@45= pH of the *longissimus lumborum* muscle at 45 min *post mortem*; pH@24= pH of the *longissimus lumborum* muscle at 24 h *post mortem*; BFT= back fat thickness; MAR= marbling; WBSF= warner bratzler shear force; SL= sarcomere length; CL= cooking loss; IMF= intramuscular fat; MUFA= monounsaturated fatty acids; PUFA= polyunsaturated fatty acids; PUFA:SFA= polyunsaturated-monounsaturated fatty acids ratio.
^{t} $P<0.1$; *$P<0.05$; **$P<0.01$; *** $P<0.001$.

Discussion

Productivity and meat quality play a key role in the meat industry, since they have a direct effect on profitability. In line with previous reports[17], no differences in HCW were observed between F and CM. The results of this study showed that CM had higher BFT and intramuscular fat content percentage than F, in agreement with values reported by other authors[18,19,20], regardless of the genetic line. The lower concentration of sexual hormones present in CM may have promoted fat deposition instead of muscle[4,5].

Loin eye area (cm^2) in samples from CM and entire F were similar with other authors[8,17]. Meat from F had higher L values than meat from CM, in line with the lower final muscle pH and higher pH rate decline from F (lower pH@45). This result may be attributed to the fact that females are more susceptible to pre-slaughter stress[21], which results in pale pork cuts.

The lack of sex effect on shear force values measured by Warner Bratzler procedure was in line with the lack of sex effect on sarcomere length. It has been suggested that sarcomere length greater than 2 µm in muscle from pigs, as in the present study, would be enough to ensure tender meats[22]. However, these results were not in agreement with the difference in rate decline observed between sexes, probably because these differences were small.

A negative correlation was observed between marbling and tenderness (r= -0.49 $P<0.05$)[23]. However, the difference in the percentage of intramuscular fat between CM and F observed in the current study does not seem to be enough to produce a significant effect on objective tenderness. This result is in agreement with the lower fibrousness values in CM that F, as indicated by visual and textural attributes and Pearson's coefficient.

Meat flavor and palatability are highly dependent on the total amount of fat and on the fatty acid profile[24]. Therefore, the level of IMF found in CM with respect to F as well as some differences in the fatty acid profile would be responsible for differences in pork flavor and odor characteristics observed in the current study. Similarly, other authors found that meat from CM had greater flavor score than meat from F samples[7,25]. The significant correlation between intramuscular fat content and FP or FC observed in the present study supports the hypothesis that intramuscular fat composition and flavor attributes could be linked.

The fatty acid profile of pork is an important factor for several sensory properties, such as flavor and firmness of tissue[26]. The flavor of pork is directly associated with the lipid oxidation that occurs during the cooking procedure[26], generating a characteristic profile of volatile compounds. The differences in some individual polyunsaturated fatty acids observed in the present study could lead to differences in the perception of flavor compounds by the sensory panel. However, such differences were very small and should be confirmed in further studies. The proportion of mono-unsaturated fatty acids was positively correlated with the characteristic flavor and its persistence[27]. In addition, as expected, a higher proportion of some individual or total polyunsaturated fatty acids seems to contribute negatively to odor and flavor attributes but positively to textural attributes in female meat[27].

Conclusions and implications

Meat from surgically CM and entire F of Argentine crossbred pigs “Degesa” (Yorkshire 25% x Landrace 75%) presented some differential quality traits in the *longissimus lumborum* muscle. CM seem to have better colorimetric and sensorial characteristics than F. The main differences observed between sexes were related to a greater amount of intramuscular fat content in meat from CM. This result implies that the sex of animals needs to be considered when producing cuts or meat products with certain quality characteristics. This means that the Argentine pork category could be differentiated by meat quality according to the sex. Further studies with a higher number of animals would be necessary to corroborate these findings.

Acknowledgments and conflict of interest

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