

## The Effects of Immunocastration on Meat Quality and Sensory Properties of Pork Bellies

Jong-Youn Jeong<sup>1</sup>, Ji-Hun Choi<sup>2</sup>, Yun-Sang Choi<sup>2</sup>, Doo-Jeong Han, Hack-Youn Kim, Mi-Ai Lee<sup>3</sup>, Duk-Hun Lee<sup>4</sup>, and Cheon-Jei Kim\*

*Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea*

*<sup>1</sup>Department of Animal Science, Michigan State University, East Lansing, MI 48824, United States*

*<sup>2</sup>Research Institute for Meat Science and Culture, Konkuk University, Seoul 143-701, Korea*

*<sup>3</sup>World Institute of Kimchi, An annex of Korea Food Research Institute, Seongnam 463-746, Korea*

*<sup>4</sup>Pfizer Animal Health Korea, Seoul 135-784, Korea*

### Abstract

This study was conducted to assess meat quality and sensory properties of pork bellies from immunocastrated males (IC) compared to meat from surgically castrated males (SC), intact males (IM), and females (FE). Pork bellies from IC had significantly higher pH values than meat from either SC or FE. Pork bellies from IC showed lower CIE L\* values than those from SC, but were redder (higher CIE a\* values) than meat from SC or FE. However, no differences in visual color were observed between pork bellies from IC and SC pigs using National Pork Producer Council scales. Water holding capacity was higher in SC and FE than that in IC. IC showed no significant difference in cooking loss and shear force values compared with those of SC. Both SC and IC had improved fat content when compared to that in IM, and IC meat showed a similar fat content to that of FE. Pork bellies from IC showed higher ratings for all visual evaluation traits than those of SC and were the same as meat from FE. Boar odor was not significantly different among the treatments. IC was rated similar to SC for taste, tenderness, and overall acceptability.

**Key words:** pork belly, immunocastration, meat quality, sensory property

### Introduction

Meat from some boars can have an offensive smell and taste, commonly known as boar taint. Boar taint is a sensory defect of pork coming mainly from entire males. It is considered to be mainly due to two compounds, skatole and androstenone (Bonneau *et al.*, 1993). Since the consumers demand pork that is free of distinct boar taint, traditionally, the surgical castration of male piglets is the common practice to avoid boar taint. (Andresen *et al.*, 1993). However, castration results in significant reductions in growth performance and excess deposition of fat (Berg *et al.*, 1993; Bonneau *et al.*, 1993). Furthermore, there are significant animal welfare concerns with surgical castration (Cambell and Taverner, 1984; Thun *et al.*, 2006). Surgical castration may result in regulations or

barriers on world's meat trading. As a more welfare-friendly alternative to surgical castration, immunization against gonadotropin releasing hormone (GnRH) has been used in various animals to suppress testicular function and avoid boar taint (Bonneau and Enright, 1995; Bonneau *et al.*, 1994; D'Souza *et al.*, 2000; Thun *et al.*, 2006). Moreover, this new practice is 99% and 100% effective in lowering skatole and androstenone, respectively (Dunshea *et al.*, 2005). In addition, the new approach has been approved for use in 55 countries around the world including Korea, Japan, Australia, and Brazil, and its use has recently approved in 2009 in the EU (European Medicines Agency, 2010; Gispert *et al.*, 2010; Pfizer Animal Health, 2010).

Many studies have demonstrated that pork from boars vaccinated to control boar taint was of the same quality as pork from female or surgically castrated pigs (Font i Furnols *et al.*, 2008; Jeong *et al.*, 2008; Pauly *et al.*, 2009, 2010). In addition, immunocastration to boars can improve meat quality as well as daily growth and feed efficiency of boars (Dikeman, 2007; Jaros *et al.*, 2005).

\*Corresponding author: Cheon-Jei Kim, Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea. Tel: 82-2-450-3684, Fax: 82-2-444-6695, E-mail: kimcj@konkuk.ac.kr

Recent studies have indicated that there was no difference in meat quality between the immunocastrates and females, entire males, or surgical castrates, and immunocastration produced an acceptable pork to consumers and was indistinguishable from pork from surgical castrates or females (Font i Furnols *et al.*, 2008; Gispert *et al.*, 2010).

In Korea, pork belly is the most popular part of the pig, accounting for 23.9% of total pork meat consumption. Large amounts of pork meat are imported and consumed up to approximately 25% of total pork meat consumption in year (Korea Meat Trade Association, 2010). Thus, understanding the eating qualities of pork bellies is a very important component of improving Korean pork's competitiveness. In addition, eliminating the boar taint is the critical issue to improve eating qualities of pork belly meat, because the boar taint and its degree of consumer dissatisfaction depends on androstenone and skatole levels in fat tissues (Bañón *et al.*, 2004; Matthews *et al.*, 2000) and further pork bellies have greater fat contents rather than other parts. However, there is very little information concerning the meat quality and the sensory attributes including the boar taint in pork bellies from immunocastrated males and other pigs.

Therefore, the aim of this study was to assess the meat quality and the sensory properties of pork bellies from immunocastrated pigs compared with surgically castrated, entire, and female pigs slaughtered at the same age.

## Materials and Methods

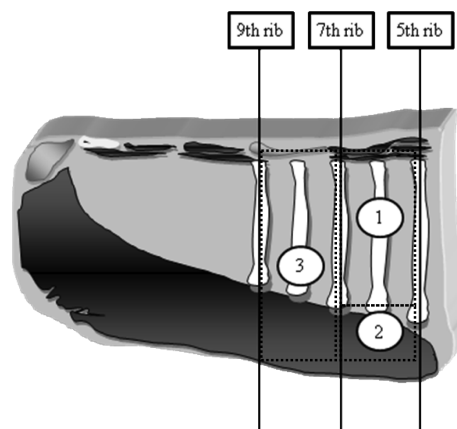
### Raw material preparation

A total of eighty Large White × Duroc crossbreed pigs (twenty of each treatment) from the same farm were randomly selected from 520 pigs (130 pigs/treatment) to supply pork bellies for this study. The pigs were allocated to the four experimental groups as followings: entire males (EM), males surgically castrated at 5 d of age (SC), males vaccinated against boar taint using Improvac<sup>®</sup> (IC), and females (FE). The animals were reared in controlled conditions at a commercial farm in Yang-Ju (Northern Kyonggi-Do, Korea) and piglets were notched in their ear with a unique identification number. Pigs were grouped into pens (13 pigs/pen, each 10 pens) with the same treatment and were fed the same diet throughout the study period. Pigs had *ad libitum* access to a standard starter diet formulation. The feeds were provided from a commercial feeding company (Rainbow Feeding Co., Ltd.) by stage of growth. Improvac<sup>®</sup> treatment (Improvac<sup>®</sup>, Pfizer Animal Health Korea, Korea) was administered subcuta-

neously behind the ear as 2 mL doses; first dose at about 9 wk and the second dose at about 20 wk of age (approximately 6 wk prior to the slaughter). Pigs were slaughtered on the same day at 26 wk of age. Eighty pigs were processed using standard commercial procedures (stunning, exsanguination, scalding, dehairing, and evisceration) and the carcasses were split into left and right sides in controlled conditions at a commercial abattoir (Korea). Approximately at 24 h postmortem after slaughtering and chilling, pork bellies (5th ribs to 9th ribs, each 1.5-2.0 kg) were removed from left side of each carcass (80 carcasses), vacuum-packaged, and transported to the Meat Science Laboratory, Konkuk University, Korea. Pork samples were kept at 4°C until the test. The area between the 5th through 7th ribs of pork bellies was used to determine meat quality traits at 48 h post-mortem (Fig. 1). Samples from between the 7th to 9th areas were also used for visual and sensory evaluations.

### pH, fat content, and water holding capacity (WHC)

To minimize the variations due to the proportion of fat/lean meat in belly parts, the samples were removed from 5th and 7th ribs of pork bellies at 48 h postmortem (Fig. 1), individually cut, and mixed with blender (Model 963009, Hermann Scharfen GmbH & Co., Germany) for the determination of pH, fat content, and WHC. A mixed sample (5 g) was homogenized with 20 mL of distilled water for 60 s in an Ultra-Turrax (Model T-25, Janke and Kunkel, Germany). The pH values of raw bellies were measured in duplicate with a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). The fat content was



**Fig. 1. Diagram of sampling locations for evaluating the meat quality and sensory properties of pork bellies.** Each number indicates the locations used for the analyses in pork belly: 1. Instrumental color, visual color, cooking loss, shear force; 2. pH value, fat content, water holding capacity; 3. Visual and sensory evaluations.

chemically determined in duplicate on samples using a solvent extraction system (AOAC, 1997; Model Avanti 2050 Auto System, Foss Tecator AB, Sweden). WHC was measured following a modification of the procedure of Grau and Hamm (1953). Briefly, a 300 mg sample was placed on a filter-press device and compressed for 3 min. WHC was calculated as a ratio of the pressed meat area to the total area.

#### **Instrumental (CIE L\*a\*b\*) and visual color**

Objective color readings were determined in duplicate on a freshly cut belly surface adjacent to between the 5th and 7th ribs at 48 h postmortem. The samples were placed on a styrofoam tray and overwrapped with oxygen permeable film. After a 30 min bloom at room temperature, the color was determined using a colorimeter (CR 210, Minolta Camera Co., Ltd., Japan; 50 mm aperture, illuminant C). The colorimeter were standardized against a white calibration plate (CIE L\* 97.83, a\* - 0.43, b\* 1.98), through the corresponding film. Also subjective measurements of visual color score were evaluated using the National Pork Producers Council (NPPC, 1999): 1 = pale pinkish gray to white, 2 = grayish pink, 3 = reddish pink, 4 = dark reddish pink, 5 = purplish red, and 6 = dark purplish red.

#### **Cooking loss and shear force determination**

The samples (5 pieces each from twenty samples per treatment) were randomly cooked to an endpoint temperature of 75°C on electric grills (Model CG20-1, Hobart Corp., USA) preheated to 180°C. The temperature of samples during cooking was monitored using an infrared thermometer (Model 66, Fluke Corporation, USA). Each piece of sample (approximate 7 mm thickness, about 23 g) was placed on the grill and cooked on the first side for 2 min and the second side for 2 min, and then turned every min until the endpoint temperature reached to 75°C. Cooked bellies were cooled at room temperature for 30 min and then cooking loss was measured.

After cooling for 1 h, each section of cooked bellies was compressed with a plate-type blade set attached to a Texture Analyzer (Model TA-XT2i, Stable Micro System Ltd., UK). Test speed was set at 2 mm/s. Shear force (N) was calculated as a maximum force to shear the samples.

#### **Visual and sensory evaluations**

A trained sensory panel was used for both visual and sensory evaluations. Initially 20 panelists began the screening

procedure. Training was given over a 4 wk period (8 sessions) in order to increase the sensitivity of the panel to androstenone (A8008, Sigma-Aldrich Corp., USA) and skatole (W301906, Sigma-Aldrich Corp., USA). After training, 12 panelists were selected, based on sensitivity to boar taint. Panelists were seated at round tables with 4 people per table and screens blocked between panelists. An electric hot-plate was centered in the middle of each table. Panelists were briefed thoroughly on the questionnaires and test methodology prior to commencement and were only informed that they would taste different pork products; they were not informed of the treatments. Before cooking, 4 pieces of raw belly were presented in the center of each table. The raw belly was scored for color, fat/meat structure, and overall preference using a 10-point category scale (10 = extremely desirable and 1 = extremely undesirable).

Immediately after evaluation of the raw meat, the samples were cooked on the electric grill at 180°C to an endpoint temperature of 75°C. Only samples from the same treatment were cooked at the same time so as to avoid cross contamination. The samples were provided in a coded manner and presented in a random manner. The hot plates were washed in warm water and unsalted crackers and water also was provided between each cooking session. Panel sessions were held on 4 d with a total of 80 samples being evaluated by each panelist (20 samples/treatment). A 10-point category scale was used for rating the different characteristics of the treatments. The cooked belly slices were assessed for aroma (boar odor), taste, tenderness, juiciness, and overall acceptability. Aroma was scored as follows: 10 = extremely intense and 1 = extremely bland. Taste and overall acceptability were scored on follows: 10 = extremely acceptable and 1 = extremely unacceptable. Tenderness and juiciness were scored on follows: 10 = extremely tender, extremely juicy; 1 = extremely tough, extremely dry.

#### **Statistical analysis**

Data for all variables of meat quality attributes were statistically analyzed using the General Linear Models (GLM) of SAS (2002) with treatment groups (SC, IC, EM, and FE) as the main effect. If significance was determined ( $p < 0.05$ ) in the model, dependent variable means were separated using Turkey's multiple range test of SAS (2002). Both visual and sensory evaluations data were pooled for across panelists and were analyzed as previously described.

## Results and Discussion

### Effects on meat qualities

#### The pH values

The pork sample from different treatments showed pH values ranging between 5.79-5.95 (Table 1). Pork bellies from IC had higher pH values ( $p<0.05$ ) than meat from SC and FE, but showed no significant difference from EM meat. When Kim *et al.* (2007) compared pork loins from entire boars, surgical castrates, and immunocastrates, they did not find significant differences in pH values, which is inconsistent with our results. Pauly *et al.* (2009) also found that pH values of pork loins did not differ among surgical castrates, entire male pigs, and immunocastrates. This disagreement between previous studies reported and present study may be due to differences in pork parts examined, because loin samples obtained from the same animals in the current study were not significantly different in pH values among the four treatments (Jeong *et al.*, 2008). Nevertheless, with the exception of IC, pH values of SC belly meat in this study were similar ( $p>0.05$ ) to those of EM or FE. These findings are similar to those of previous researches (Bañón *et al.*, 2004; Sather *et al.*, 1999).

#### Instrumental (CIE L\*a\*b\*) and visual color

Pork bellies from SC had higher ( $p<0.05$ ) CIE L\* values (lightness) than the other treatments (IC, EM, and FE) which are similar ( $p>0.05$ ) to one another (Table 1). This result is similar to that of Silveira *et al.* (2008) who found significantly higher CIE L\* values in surgically

castrated males than in immunologically castrated pigs. In the case of CIE a\*, meat from IC was redder (higher CIE a\* values;  $p<0.05$ ) than meat from SC or FE, but not significantly different from EM meat (Table 1). However, no significant differences in CIE a\* values were observed for SC, EM, and FE. Both castration treatments (SC and IC) showed more yellow color (higher CIE b\* values) compared to EM and FE, but there were no significant differences in CIE b\* values between pork meat from SC and IC, or EM and FE (Table 1).

When surface color of pork bellies was subjectively made by NPPC scales, visual color scores were the highest value ( $p<0.05$ ) in FE (3.67), and was not significantly different among SC (3.41), IC (3.38), and EM (3.28) (Table 1). Although significant, differences in the scores ranging from 3.28 to 3.67 were minimal. Thus, pork bellies obtained for this study maintained a normal color (between reddish pink and dark reddish pink) regardless of castration practices or gender of animals.

#### Water holding capacity (WHC)

The WHC was lower ( $p<0.05$ ) in samples from IC than those from SC and FE, but not different ( $p>0.05$ ) between IC and EM samples (Table 1). Pork bellies from SC, EM, and FE had a similar WHC ( $p>0.05$ ) as was reported by D'Souza and Mullan (2003) for pork loins from surgically castrated males and females. Jeong *et al.* (2008) found no significant differences in WHC for loin meat from the same four treatments as in the present study. This result is partially in accordance with the present study, although a decrease in WHC of IC meat was observed in our results. However, D'Souza *et al.* (2000) found that

**Table 1. The meat quality characteristics of pork bellies from immunocastrated males compared with surgically castrated males, entire males, and females**

| Traits                            | Treatments <sup>1</sup>  |                         |                          |                         |
|-----------------------------------|--------------------------|-------------------------|--------------------------|-------------------------|
|                                   | SC                       | IC                      | EM                       | FE                      |
| pH                                | 5.79±0.03 <sup>B</sup>   | 5.95±0.04 <sup>A</sup>  | 5.83±0.03 <sup>AB</sup>  | 5.79±0.03 <sup>B</sup>  |
| CIE L*                            | 61.27±0.51 <sup>A</sup>  | 58.43±0.50 <sup>B</sup> | 56.74±0.42 <sup>B</sup>  | 57.49±0.64 <sup>B</sup> |
| CIE a*                            | 12.98±0.27 <sup>B</sup>  | 14.56±0.30 <sup>A</sup> | 13.77±0.15 <sup>AB</sup> | 13.20±0.17 <sup>B</sup> |
| CIE b*                            | 4.60±0.08 <sup>A</sup>   | 4.54±0.09 <sup>A</sup>  | 3.39±0.10 <sup>B</sup>   | 3.50±0.08 <sup>B</sup>  |
| Visual color (NPPC <sup>2</sup> ) | 3.41±0.07 <sup>B</sup>   | 3.38±0.06 <sup>B</sup>  | 3.28±0.06 <sup>B</sup>   | 3.67±0.06 <sup>A</sup>  |
| Water holding capacity (%)        | 36.14±0.61 <sup>A</sup>  | 32.82±0.96 <sup>B</sup> | 34.00±0.80 <sup>AB</sup> | 36.25±1.12 <sup>A</sup> |
| Cooking loss (%)                  | 31.26±0.32 <sup>AB</sup> | 31.01±0.35 <sup>B</sup> | 30.74±0.48 <sup>B</sup>  | 32.64±0.38 <sup>A</sup> |
| Shear force (N)                   | 90.91±1.54               | 82.79±2.26              | 84.95±2.64               | 87.88±2.22              |
| Fat content (%)                   | 21.07±0.47 <sup>A</sup>  | 18.25±0.42 <sup>B</sup> | 15.78±0.59 <sup>C</sup>  | 18.66±0.67 <sup>B</sup> |

All values are mean±SE.

<sup>1</sup>SC: surgically castrated males, IC: immunocastrated males, EM: entire males, FE: females

<sup>2</sup>NPPC: National Pork Producers Council

<sup>A-C</sup>Means within a row with unlike superscript letters are significantly different ( $p<0.05$ ).

pork loins from Improvac vaccinated (immunocastrated) male pigs and entire males exhibited a higher WHC compared to meat from female pigs.

### Cooking loss

Cooking loss ranged from 30.74 to 32.64% and bellies from SC had similar ( $p>0.05$ ) cooking loss to meat from IC, EM, or FE (Table 1). Kim *et al.* (2007) and Pauly *et al.* (2009) found that cooking loss did not significantly differ among loins from the castrates, immunocastrated boars, and entire males, in accordance with the present results. However, meat from IC and EM showed a lower ( $p<0.05$ ) cooking loss than meat from FE. Eikelenboom and Hoving-Bolink (1993) reported samples from gilts having greater cooking losses than the meat from surgical castrates, but no differences ( $p>0.05$ ) in cooking loss between SC and FE were found in the current study.

### Shear force value

The shear force of pork bellies may depend on the structures or ratio of the meat tissue and the fat layer. Thus, to minimize variation between the samples, in the present experiment, shear force was measured on 100 pieces (5 pieces from each of 20 samples) per treatment using a plate-type blade set. Shear force values of pork bellies were similar ( $p>0.05$ ) among treatments (SC, IC, EM, and FE) (Table 1). This agrees with work done by Kim *et al.* (2007), who found no significant differences in shear force values among loin meat from entire boars, surgical castrates, and immunocastrates. Our results demonstrated that immunocastration by vaccination to boars caused a similar on shear force values of pork bellies when compared against surgical castrates under condition tested in this study.

### Fat content

SC was the fattest (21.07%) in the belly and EM was the leanest (15.78%), while IC (18.25%) and FE (18.66

%) were intermediate ( $p<0.05$ ) (Table 1). Similarly, Park *et al.* (2009) reported that belly meat from barrows (surgically castrated boars) had a great fat content than gilts (females). Gispert *et al.* (2010) reported that castrated males were the fattest and entire males the leanest in the ham area, while immunocastrated males and females were in between. Jeremiah *et al.* (1999) also found that barrows (castrated boars) showed a higher marbling score than gilts (females) or entire boars. Comparing immunocastration with surgical castration, the yield of lean meat was significantly lower in immunocastrates than surgical castrates (Jaros *et al.*, 2005), which is similar to our results. In addition, D'Souza *et al.* (2000) and Pauly *et al.* (2009) have demonstrated that immunocastrated boars showed a higher marbling score than entire males.

## Effects on visual and sensory evaluations

### Visual evaluations

Visual evaluations were made for color, fat/meat structure, and overall preference before cooking pork bellies, and the results are presented in Table 2. The color of IC and FE samples was rated higher scores ( $p<0.05$ ) than that of SC but not significantly different from that of EM meat which was similar to that of SC meat. These results were similar to the trends in CIE  $a^*$  values in this study. It seems likely that redness of pork bellies is considered to be acceptable indicator and redder bellies from IC with respect to meat from SC were probably preferred by Korean panelists tested in present study. Since the ratio between fat and meat within pork bellies is not prescribed by regulations or any indexes, it may depend on preferences of individuals from their habits, experiences for eating meat, or other factors. Nevertheless, fat/meat structure was rated the highest scores in bellies from IC and FE ( $p<0.05$ ), but lowest in samples from SC and EM ( $p<0.05$ ). The overall preference of IC bellies was higher than that of SC and EM meat ( $p<0.05$ ) but not signifi-

**Table 2. Visual properties<sup>1</sup> of raw pork bellies from immunocastrated males compared with surgically castrated males, entire males, and females**

| Traits             | Treatments <sup>2</sup> |                        |                         |                         |
|--------------------|-------------------------|------------------------|-------------------------|-------------------------|
|                    | SC                      | IC                     | EM                      | FE                      |
| Color              | 7.76±0.06 <sup>B</sup>  | 8.07±0.05 <sup>A</sup> | 7.88±0.05 <sup>AB</sup> | 8.01±0.06 <sup>A</sup>  |
| Fat/meat structure | 7.58±0.07 <sup>B</sup>  | 8.03±0.06 <sup>A</sup> | 7.78±0.06 <sup>B</sup>  | 8.01±0.06 <sup>A</sup>  |
| Overall preference | 7.69±0.06 <sup>C</sup>  | 8.11±0.05 <sup>A</sup> | 7.83±0.05 <sup>BC</sup> | 8.01±0.06 <sup>AB</sup> |

All values are mean±SE.

<sup>1</sup>Scores based on 10-point scale, where 10= extremely desirable and 1= extremely undesirable

<sup>2</sup>SC: surgically castrated males, IC: immunocastrated males, EM: entire males, FE: females

<sup>A-C</sup>Means within a row with unlike superscript letters are significantly different ( $p<0.05$ ).

cantly different ( $p>0.05$ ) from FE samples. In addition, SC showed a lower overall preference ( $p<0.05$ ) than FE but was not significantly different from EM. When summarizing visual evaluations results, IC had higher ratings ( $p<0.05$ ) than SC in color, fat/meat structure and overall preference, and were similar ( $p>0.05$ ) to FE for all attributes evaluated, which could positively affect decisions for purchasing pork bellies by consumers.

### Sensory evaluations

Comparison on sensory properties of cooked pork bellies between immunocastrates, surgical castrates, entire males, and females is shown in Table 3. The mean scores of aroma (boar odor) were lower than 3.5, and no significant difference was observed among the treatments (SC, IC, EM, and FE). Similar results were reported in other consumer studies for meat from entire males, castrated males, and females (Cowan and Joseph, 1981; Nold *et al.*, 1997; Rhodes, 1971). Interestingly, IC has the same effect on boar odor with respect to SC in these tested conditions. Recently reported studies indicated that there were no differences in boar odor when surgical castrates and immunocastrates were compared (Font i Furnols *et al.*, 2008; Jeong *et al.*, 2008; Pauly *et al.*, 2010). The higher correlation between boar taint and both androstenone and skatole content has been noted by many researchers (Andressen *et al.*, 1993; Berg *et al.*, 1993; Bonneau *et al.*, 1993; Desmoulin *et al.*, 1982; Font i Furnols *et al.*, 2009; Froystein *et al.*, 1993, 1980; Lundstrom *et al.*, 1988). It has been demonstrated that immunization against gonadotrophin-releasing factor (GnRF) to boars can contribute to an effective control of boar taint in pork meat (Dunsha *et al.*, 2001; Font i Furnols *et al.*, 2008, 2009; Jaros *et al.*, 2005; McCauley *et al.*, 2003). Moreover, Pauly *et al.*

(2009) noted that the androstenone, skatole, and indole concentrations in the adipose tissue of all immunocastrated pigs were clearly below the sensory thresholds. Our results confirmed that boar odor in belly meat could be reduced by immunocastration as well as surgical castration of boars. However, panelists participated in sensory evaluations could not differentiate among the treatments for boar odor, even for meat from entire males, although they were trained with androstenone and skatole for boar odor. Repeated exposure to both compounds tends to increase sensitivity to these compounds (Wysocki and Beauchamp, 1984). The perception of individual humans to boar odor varies widely by consumer gender (Griffiths and Patterson, 1970; Matthews *et al.*, 2000; Wysocki and Beauchamp, 1984), habitual frequency (Babol and Squires, 1995; Matthews *et al.*, 2000), and the variety of culinary habits between countries (Bonneau *et al.*, 2000; Bonneau and Lebret, 2010; Matthews *et al.*, 2000).

Taste of cooked pork bellies was not shown any significant differences among the four treatments (SC, IC, EM, and FE). This result might be affected by boar taint in pork bellies (Bañón *et al.*, 2004). In tenderness, there were also no significant differences between IC and the other treatments (SC, EM, or FE). However, bellies from EM had less tender than meat from SC and FE. Similar results were found by Font i Furnols *et al.* (2009), who reported that meat from entire males had higher toughness scores than meat from surgically castrated, and immunocastrated male pigs, while there were no significant differences between meat from immunocastrated males and females when trained panelists evaluated pork loins. Pork bellies from SC received the highest juiciness scores ( $p<0.05$ ), while no significant difference was observed among the other treatments (IC, EM, and FE). More

**Table 3.** Sensory properties<sup>1)</sup> of cooked pork bellies from immunocastrated males compared with surgically castrated males, entire males, and females

| Traits                | Treatments <sup>2)</sup> |                         |                        |                         |
|-----------------------|--------------------------|-------------------------|------------------------|-------------------------|
|                       | SC                       | IC                      | EM                     | FE                      |
| Aroma (boar odor)     | 2.58±0.10                | 3.28±0.10               | 3.05±0.10              | 2.56±0.08               |
| Taste                 | 7.78±0.06                | 7.58±0.06               | 7.62±0.06              | 7.73±0.06               |
| Tenderness            | 7.87±0.05 <sup>A</sup>   | 7.67±0.06 <sup>AB</sup> | 7.56±0.06 <sup>B</sup> | 7.77±0.06 <sup>A</sup>  |
| Juiciness             | 8.05±0.05 <sup>A</sup>   | 7.82±0.05 <sup>B</sup>  | 7.78±0.05 <sup>B</sup> | 7.81±0.05 <sup>B</sup>  |
| Overall acceptability | 7.78±0.06 <sup>A</sup>   | 7.55±0.07 <sup>AB</sup> | 7.52±0.07 <sup>B</sup> | 7.74±0.07 <sup>AB</sup> |

All values are mean±SE.

<sup>1)</sup>Scores based on 10-point scale, where 10 = extremely intense and 1 = extremely bland for aroma (boar odor), 10 = extremely acceptable and 1 = extremely unacceptable for taste and overall acceptability, 10 = extremely tender, extremely juicy; 1 = extremely tough, extremely dry for tenderness and juiciness.

<sup>2)</sup>SC, surgically castrated males; IC, immunocastrated males; EM, entire males; FE, females

<sup>A,B</sup>Means within a row with unlike superscript letters are significantly different ( $p<0.05$ ).

acceptability of bellies from SC may be related to their fat content. Related to fat content, Bañón *et al.* (2004) found that the meat of castrates was juicier and more tender than meat from entires when there were significant differences in the amount of intramuscular fat. It is possible that lower intramuscular fat in entire male pigs, related to the reduced carcass fatness, may be responsible for the lower tenderness and juiciness (Bonneau and Lebret, 2010).

In this study, bellies from IC did not show any significant differences from the other treatments (SC, EM, and FE) for overall acceptability, while SC had higher scores compared to EM. These results are similar to those of Bañón *et al.* (2004), who found that pork loin acceptance was better in surgical castrates than in entire males. Similarly, D'Souza and Mullan (2003) reported that pork from entire males was significantly less acceptable when judged by a consumer panel compared with pork from the surgically and immunologically castrated male pigs. Recently, Gispert *et al.* (2010) have indicated that surgically and immunologically castrated males among the same four treatments as in the present study were characterized by relatively higher levels of fat and high acceptability of odor and taste by consumer. Therefore, even though there was no difference in boar odor and taste in our results, relatively less fat levels in bellies from entire male pigs could be responsible for dissatisfaction of meat (Bañón *et al.*, 2004; D'Souza and Mullan, 2003).

In conclusion, pork bellies from IC were similar to meat from SC in visual color, cooking loss, and shear force. Also, visual properties of raw bellies showed higher ratings IC than SC and EM. In addition, no difference was observed in boar odor among the treatments and meat from IC and FE were judged to be of the same sensory properties. Therefore, these results suggest that immunocastration could serve as effective and suitable alternatives to avoid surgical castration and produce more efficient boars free of animal welfare issues with no negative effects on pork quality.

### Acknowledgment

Authors would like to thank Pfizer Animal Health Korea for supplying funding and raw materials for this research. The authors were partially supported by the Brain Korea 21 (BK21) Project from Ministry of Education and Human Resources Development.

### References

1. Andressen, Ø., Frøystein, T., Rødbotten, M., Mortensen, H. P., Eik-Nes, O., and Lea, P. (1993) Sensoric evaluation of boar meat with different levels of androstenone and skatole. In: Measurement and prevention of boar taint in entire male pigs. Bonneau, M. (ed) INRA Editions, Paris, France, pp. 69-73.
2. AOAC (1997) Official methods of analysis. 16th ed, Association of Official Analytical Chemists, Washington, DC, pp. 3-4 (chapter 39).
3. Babol, J. and Squires, E. J. (1995) Quality of meat from entire male pigs. *Food Res. Int.* **28**, 201-212.
4. Bañón, S., Andreu, C., Laencian, J., and Garrido, M-D. (2004) Fresh and eating pork quality from entire versus castrate heavy males. *Food Qual. Prefer.* **15**, 293-300.
5. Berg, H., Agerhem, H., von Seth, G., and Tornberg, E. (1993) The relationship between skatole and androstenone content and sensory off-odour in entire male pigs. In: Measurement and prevention of boar taint in entire male pigs. Bonneau, M. (ed) INRA Editions, Paris, France, pp. 55-62.
6. Bonneau, M. and Lebret, B. (2010) Production systems and influence on eating quality of pork. *Meat Sci.* **84**, 293-300.
7. Bonneau, M. and Enright, W. J. (1995) Immunocastration in cattle and pigs. *Livest. Prod. Sci.* **42**, 193-200.
8. Bonneau, M., Dufour, R., Chouvet, C., Roulet, C., Meadus, W., and Squires, E. J. (1994) The effects of immunization against luteinizing hormone-releasing hormone on performance, sexual development, and levels of boar taint-related compounds in intact male pigs. *J. Anim. Sci.* **72**, 14-20.
9. Bonneau, M., Le Denmat, M., Mortensen, A. B., and Mortensen, H. P. (1993) Relationships between fat androstenone and skatole levels and the organoleptic assessment of pork and cooked ham. In: Measurement and prevention of boar taint in entire male pigs. Bonneau, M. (ed) INRA Editions, Paris, France, pp. 81-86.
10. Bonneau, M., Walstra, P., Claudi-Magnussen, C., Kempster, A. J., Tornberg, E., Fischer, K., Diestre, A., Siret, F., Chevillon, P., Claus, R., Dijksterhuis, G., Punter, P., Matthews, K. R., Agerhem, H., Beague, M. P., Oliver, M. A., Gispert, M., Weiler, U., Von Seth, G., Leask, H., Font i Furnolls, M., Homer, D. B., and Cook, G. L. (2000) An international study on the importance of androstenone and skatole for boar taint: IV. Simulation studies on consumer dissatisfaction with entire male pork and the effect of sorting out carcasses on the slaughter line, main conclusions and recommendations. *Meat Sci.* **54**, 285-295.
11. Cambell, R. G. and Taverner, M. R. (1988) Genotype and sex effects on the relationship between energy intake and protein deposition in growing pigs. *J. Anim. Sci.* **66**, 676-686.
12. Cowan, C. A. and Joseph, R. L. (1981) Production and quality of boar and castrate bacon. 2. Consumer and panel response to bacon and fat samples. *Zr. J. Food Sci. Technol.* **5**, 105-116.
13. D'Souza, D. N. and Mullan, B. P. (2003) The effect of genotype and castration method on the eating quality characteris-

- tics of pork from male pigs. *Anim. Sci.* **77**, 67-72.
14. D'Souza, D. N., Hennessy, D., Danby, M., McCauley, I., and Mullan, B. P. (2000) The effect of Improvac1 on pork quality. *J. Anim. Sci.* **78** (Suppl. 1), 158.
  15. Desmoulin, B., Bonneau, M., Frouin, A., and Bidard, J. F. (1982) Consumer testing of pork and processed meat from boars: the influence of fat androstenone level. *Livest. Prod. Sci.* **9**, 707-715.
  16. Dikeman, M. E. (2007) Effects of metabolic modifiers on carcass traits and meat quality. *Meat Sci.* **77**, 121-135.
  17. Dunshea, F. R., Colantoni, C., Howard, K., McCauley, I., Jackson, P., Long, K. A., Lopaticki, S., Nugent, E. A., Simons, J. A., Walker, J., and Hennessy, D. P. (2001) Vaccination of boars with a GnRH vaccine (Improvac) eliminates boar taint and increases growth performance. *J. Anim. Sci.* **79**, 2524-2535.
  18. Dunshea, F. R., D'Souza, D. N., Pethick, D. W., Harper, G. S., and Warner, R. D. (2005) Effects of dietary factors and other metabolic modifiers on quality and nutritional value of meat. *Meat Sci.* **71**, 8-38.
  19. Eikelenboom, G. and Hoving-Bolink, R. (1993) Pork quality. Effects of feed composition, sex, and slaughter time. *Fleischwirtschaft* **73**, 648-650.
  20. European Medicines Agency. (2010) European public assessment report (EPAR): Improvac. Available from: [http://www.ema.europa.eu/docs/en\\_GB/document\\_library/EPAR\\_Summary\\_for\\_the\\_public/veterinary/000136/WC500064055.pdf](http://www.ema.europa.eu/docs/en_GB/document_library/EPAR_Summary_for_the_public/veterinary/000136/WC500064055.pdf). Accessed Apr. 18, 2011.
  21. Font i Furnols, M., Gispert, M., Guerrero, L., Velarde, A., Tibau, J., Soler, J., Hortós, M., García-Regueiro, J. A., Pérez, J., Suárez, P., and Oliver, M. A. (2008) Consumers' sensory acceptability of pork from immunocastrated male pigs. *Meat Sci.* **80**, 1013-1018.
  22. Font i Furnols, M., González, J., Gispert, M., Oliver, M. A., Hortós, M., Pérez, J., Suárez, P., and Guerrero, L. (2009) Sensory characterization of meat from pigs vaccinated against gonadotropin releasing factor compared to meat from surgically castrated, entire male and female pigs. *Meat Sci.* **83**, 438-442.
  23. Froystein, T., Wittussen, H. T., Roe, M., Bye, M., and Bjomstad, A. (1993) Entire male production in small scale slaughterhouses based on manual analysis of skatole. In: Measurement and prevention of boar taint in entire male pigs. Bonneau, M. (ed) INRA Editions, Paris, France, pp. 145-150.
  24. Gispert, M., Oliver, M. À., Velarde, A., Suarez, P., Pérez, J., and Font i Furnols, M. (2010) Carcass and meat quality characteristics of immunocastrated male, surgically castrated male, entire male and female pigs. *Meat Sci.* **85**, 664-670.
  25. Grau, R. and Hamm, R. (1953) A simple method for the determination of water binding in muscles. *Naturwissenschaften* **40**, 29.
  26. Griffiths, N. M. and Patterson, R. L. S. (1970) Human olfactory responses to 5-androst-16-EN-3-one-principal component of boar taint. *J. Sci. Food Agric.* **21**, 4-6.
  27. Jaros, P., Bürgi, E., Stärk, K. D. C., Claus, R., Hennessy, D., and Thun, R. (2005) Effect of active immunization against GnRH on androstenone concentration, growth performance and carcass quality in intact male pigs. *Livest. Prod. Sci.* **92**, 31-38.
  28. Jeong, J. Y., Choi, J. H., Han, D. J., Lee, D. H., Hennessy, D., and Kim, C. J. (2008) The effects of immunocastration on meat quality and sensory properties of pork loins. Proceed. 20th Int. Pig Vet. Soc. Cong., Durban, South Africa, pp. 269.
  29. Jeremiah, L. E., Gibson, J. P., Gibson, L. L., Ball, R. O., Aker, C., and Fortin, A. (1999) The influence of breed, gender, and PSS (Halothane) genotype on meat quality, cooking loss, and palatability of pork. *Food Res. Int.* **32**, 59-71.
  30. Kim, Y. H., Jung, H. J., Lee, S. D., Ji, S. Y., Park, J. C., and Moon, H. K. (2007) Effects of immunocastration on physiological changes, the characteristics of carcass and meat quality in boars. *J. Anim. Sci. Technol.* **49**, 753-760.
  31. Korea Meat Trade Association. (2010) Annual Handbook of Meat. Available from: <http://www.kmta.or.kr/html/sub5-2.html?board=report04>. Accessed Apr. 23, 2010.
  32. Lundstrom, K., Malmfors, B., Malmfors, G., Stem, S., Peterson, H., Mortensen, A. B., and Sorensen, S. E. (1988) Skatole, androstenone and taint in boars fed two different diets. *Livest. Prod. Sci.* **18**, 55-63.
  33. Matthews, K. R., Homer, D. B., Punter, P., Beague, M. P., Gispert, M., Kempster, A. J., Agerhem, H., Claudi-Magnussen, C., Fischer, K., Siret, F., Leask, H., Font i Furnols, M., and Bonneau, M. (2000) An international study on the importance of androstenone and skatole for boar taint. III. Consumer survey in seven European countries. *Meat Sci.* **54**, 271-283.
  34. McCauley, I., Watt, M., Suster, D., Kerton, D. J., Oliver, W. T., Harrell, R. J., and Dunshea, F. R. (2003) A GnRF vaccine (Improvac®) and porcine somatotropin (Reporcin®) have synergistic effects upon growth performance in both boars and gilts. *Aust. J. Agric. Res.* **54**, 11-20.
  35. Nold, R. A., Romans, J. R., Costello, W. J., Henson, J. A., and Libal, G. W. (1997) Sensory characteristics and carcass traits of boars, barrows, and gilts fed high- or adequate-protein diets and slaughtered at 100 or 110 kilograms. *J. Anim. Sci.* **75**, 2641-2651.
  36. NPPC (1999) Pork quality standards. National Pork Producers Council publication, Des Moines, IA, USA.
  37. Park, M. J., Jeong, J. Y., Ha, D. M., Han, J. C., Sim, T. G., Park, B. C., Park, G. B., Joo, S. T., and Lee, C. Y. (2009) Effects of dietary energy level and slaughter weight on growth performance and grades and quality traits of the carcass in finishing pigs. *J. Anim. Sci. Technol.* **51**, 143-154.
  38. Pauly, C., Spring-Staehli, P., O'Doherty, J. V., Kragten, S. A., Dubois, S., Messadène, J., and Bee, G. (2010) The effects of method of castration, rearing condition and diet on sensory quality of pork assessed by a trained panel. *Meat Sci.* **86**, 498-504.
  39. Pauly, C., Spring, P., O'Doherty, J. V., Kragten, S. A., and Bee, G. (2009) Growth performance, carcass characteristics and meat quality of group-penned surgically castrated, immunocastrated (Improvac®) and entire male pigs and individually penned entire male pigs. *Animal* **3**, 1057-1066.
  40. Pfizer Animal Health. (2010) JMAFF approves Pfizer Ani-



- mal Health's IMPROVAC<sup>®</sup> as safe and effective for pig in Japan. Available from: [http://www.improvac.com/sites/Improvac/zh-CN/PressCentre/JMAFF\\_Japan.pdf](http://www.improvac.com/sites/Improvac/zh-CN/PressCentre/JMAFF_Japan.pdf). Accessed Apr. 18, 2011.
41. Rhodes, D. N. (1971) Consumer testing of bacon from boar and gilt pigs. *J. Sci. Food Agric.* **22**, 485-490.
  42. SAS (2002) SAS user's guide. SAS Institute, Inc., Cary, NC, USA.
  43. Sather, A. P., Jeremiah, L. E., and Squires, E. J. (1999) Effects of castration on live performance, carcass yield, and meat quality of male pigs fed wheat or corn based diets. *J. Muscle Foods* **10**, 245-259.
  44. Silveira, E. T. F., Poleze, E., Oliveira, F. T. T., Tonietti, A. P., Andrade, J. C., and Hagiwara, M. M. H. (2008) Vaccination of boars with GnRF vaccine (Improvac) and its effects on meat quality. Proceed. 20th Int. Pig Vet. Soc. Cong., Durban, South Africa, pp. 590.
  45. Thun, R., Gajewski, Z., and Janett, F. (2006) Castration in male pigs: techniques and animal welfare issues. *J. Physiol. Pharmacol.* **57**, 189-194.
  46. Wysocki, C. J. and Beauchamp, G. K. (1984) Ability to smell androstenone is genetically determined. *P. Natl. Acad. Sci. USA* **81**, 4899-4902.

---

(Received 2010.11.19/Revised 2011.5.3/Accepted 2011.5.9)