

A summary review of carcass cutability data comparing primal value of immunologically and physically castrated barrows

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ABSTRACT: The objectives were to 1) assess cutability, quality, and value of carcasses from immunologically castrated (IC) barrows compared with carcasses from physically castrated (PC) barrows and 2) evaluate the effect of hot carcass weight (HCW) on cutability and value of IC barrows summarizing U.S. data. Lean cutting yield (LCY) was defined as: $LCY = [(whole\ ham + trimmed\ loin + Boston\ butt + picnic + spareribs)/chilled\ side\ wt] \times 100$. Carcass cutting yield (CCY) was determined using the following equation: $CCY = [(lean\ cutting\ yield\ components + natural\ fall\ belly)/chilled\ side\ wt] \times 100$. To evaluate the effects of HCW of IC barrows on carcass cutting yields, IC barrows were grouped by HCW: light (< 90.9 kg), average (90.9- 97.7 kg), or heavy (> 97.7 kg). Differences in the value of the carcass components for IC and PC barrow carcasses were calculated using a 5 yr average of meat prices from the USDA Agriculture Marketing Service and the carcass cutting yield estimates generated from this summary. Data were analyzed using the MIXED procedure of SAS with fixed effects of Improvest treatment or HCW group. Study was included as a random effect. This review allowed for a summarization of the

treatment averages of 851 IC and PC barrow carcasses. Lean cutting yield of IC barrows was 1.41 units greater ($P < 0.0001$) than PC barrows (70.97 vs. 69.56%). Similarly, CCY of IC barrows was 1.29 units greater ($P < 0.001$) compared with PC barrows (87.27 vs. 85.98%). As HCW of IC barrows increased, both CCY and LCY declined ($P < 0.01$), with light IC barrow carcasses having a 1.43 unit advantage in CCY compared with heavy IC barrow carcasses ($P < 0.01$). Natural fall bellies of PC barrows comprised a greater ($P < 0.05$) percentage of side weight than those from IC barrows (15.81 vs. 15.50%). A reduction in belly primal value was confirmed by a 3.43 unit reduction in the commercial bacon slicing yields of IC barrows. However, belly yield and slicing yield differences were minimized when IC barrows were marketed at a heavier weight. Using carcass cutout estimates determined in the summary as the foundation for value calculations, lean cuts of IC barrow carcasses were worth \$2.66 to \$3.80 more than PC barrow carcasses. Therefore, after adjustment for the reduction in belly primal value, the primal value of an IC barrow carcass was \$2.08 to \$3.13 greater than a PC barrow carcass.

Key words: belly quality, cutability, gonadotropin-releasing factor, Improvest, pork

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INTRODUCTION

For any technology to gain industry-wide adoption, it must provide value to all segments of the industry and have minimal associated risks. Immunological castra-

tion (Improvest, Zoetis Inc., Kalamazoo, MI, *GnRF analog-diphtheria toxoid conjugate*) provides an effective alternative to physical castration for reducing boar odor of intact male pigs while improving lean deposition compared with physically castrated (PC) barrows. The effects of immunological castration on growth performance (Dunshea et al., 2013), carcass cutability (Boler et al., 2011a, 2012) and belly quality (Kyle et al., 2014; Tavárez et al., 2016) have been well

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documented in a number of studies. However, because experimental objectives differed among research studies, true differences in cutability and other carcass traits between IC and PC carcasses are not clear. Production factors such as diet (Tavárez et al., 2014), interval between second Improvest injection and slaughter (Boler et al., 2012; Tavárez et al., 2016), marketing group (Lowe et al., 2014), and the use of ractopamine hydrochloride (Lowe et al., 2014; 2016b) all affect cutting yield, belly characteristics, and meat quality attributes of immunologically castrated (IC) barrows. Herrick et al. (2016) demonstrated belly quality of IC barrow carcasses is particularly dependent on HCW. However, the effect of HCW on cutability of other carcass components, as well as meat quality traits, has not been characterized. Although comprehensive meta-analyses have been conducted to determine the average effects of immunological castration on live performance (Dunsha et al., 2013) and elimination of boar odor compounds (Batorek et al., 2012), these reviews have not evaluated the effects on carcass cutability, quality, and value. Therefore, the objectives of this work were to assess the carcass value of IC barrows compared with PC barrows and to evaluate the effect of hot carcass weight (HCW) on IC barrow carcass cutability and value.

MATERIALS AND METHODS

A comprehensive summary provides a quantitative, statistical approach to the summarization of previous literature and scientific findings (Sauvant et al., 2008). By compiling the results of studies, statistical power increases enabling more precise estimates of the magnitude of effect and confidence limits (Sauvant et al., 2008). As a result, the information provided provides greater understanding of the previous results through a more comprehensive overview which ultimately allows for consensus to be drawn.

Study Selection Criteria

Although comprehensive summaries allow for the aggregation of multiple studies, an analysis may not necessarily include all previous findings. Determining which studies match summary objectives is of critical importance (Sauvant et al., 2008). Ultimately, using specific pre-defined inclusion criteria allows for appropriate industry application of the results. Pigs in all the studies included in this review were administered Improvest according to United States label requirements at the time they were administered. To mirror current industry feeding practices, studies in which dried distillers grains with solubles (DDGS) as well ractopamine hydrochloride (RAC) was fed were included.

To ensure relevance to U.S. packers, only studies using U.S. cutting standards were included in the carcass cutting yield analyses. For inclusion in the bacon processing characteristics analysis, bellies must have been commercially processed under the supervision of the USDA Food Safety and Inspection Service. Hams fabricated to meet the specification of a NAMP #401 (NAMP, 2007) were designated as whole hams. Trimmed hams were those fabricated to meet the specification of a NAMP #402 ham, skinned and trimmed of excess fat. Skin and fatback (subcutaneous fat along the lateral portion of the loin) on bone-in loins were designated as whole loins. Trimmed loins were those fabricated to meet the specification of a NAMP #410 loin. Bone-in Boston butt was designated as skinned, clear plate-removed shoulders fabricated to meet the specification of a NAMP #406. Modified, skinned NAMP #405 were designated as a bone-in picnic. Bone-in picnics that were further fabricated were designated as a boneless picnic shoulder (NAMP #405A) and cushion (triceps brachii; NAMP #405B).

Because ending live weights varied from study to study as a result of differences in study BW endpoints and objectives, emphasis was placed on percentage of chilled side weight each component comprises as well as the magnitude of difference between IC and PC barrows for each component. Lean cutting yield (LCY) and carcass cutting yield (CCY) were calculated using the following equations:

$$\text{Bone in LCY} = \frac{[(\text{Boston butt} + \text{picnic shoulder} + \text{trimmed loin} + \text{whole ham} + \text{spareribs}) / (\text{chilled side weight})] \times 100}$$

$$\text{Bone in CCY} = \frac{[(\text{Lean cutting yield components} + \text{natural fall belly}) / (\text{chilled side weight})] \times 100}$$

A total of seven studies matched the pre-defined inclusion criteria for evaluating the effects of Improvest on carcass cutability and primal yields. These studies include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016a, 2016b), Tavárez et al. (2014), and Harris (2014). Within the belly quality characteristic evaluation, 7 studies were used: Boler et al. (2011b, 2012), Kyle et al. (2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), and Harris (2014). Loin quality summaries were conducted using 8 studies: Pauly et al. (2009), Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), Harris (2014), and Elsbernd et al. (2016). Some studies included more than 1 experiment and data meeting criteria for cutability and belly analyses were included in both analyses.

Treatment Analyses (IC Barrows vs. PC Barrows)

Because immunological castration is a technology designed to provide an alternative to physical castration, the most relevant comparison in the U.S. pork industry for the IC barrow carcass cutting yields and belly characteristics, is with PC barrows. Overall, this analysis allowed for a summarization of the treatment averages for total 851 carcasses.

Hot Carcass Weight Analyses

Marketing finished pigs in groups, or cuts has become a common strategy to maximize the number of pigs meeting a target BW at the time of slaughter (Meyer, 2005). The current labeled marketing period for male pigs treated with Improvest is from 3 to 10 wk (21 to 70 d) after the second dose of Improvest. This time period allows for the reduction of boar odor compounds and ensures slaughter before boar odor compounds reappear. This flexible marketing window enables producers to use a variety of different marketing strategies. After the second Improvest dose, the weight of IC barrows continues to increase and transition, compositionally, toward greater fat deposition (Lowe et al., 2014).

The effect of IC barrow HCW on carcass cutability and belly characteristics in relation to packer-derived revenue is not well defined. To analyze the effect of HCW, carcasses of IC barrows were categorized as light (< 90.9 kg), average (90.9 to 97.7 kg) or heavy (> 97.7 kg). Carcass weight bins were fit to the available data with the average HCW category encompassing the average HCW (93.2 kg) that was used for cutout value estimations in the 2016 USDA carlot report (USDA, AMS, Livestock & Seed Program, Livestock, & Grain Market News, 2016). In total, this resulted in a summarization of the treatment averages for 491 carcasses.

Value Calculations

The carcass cutout estimates resulting from the current review were used as a basis for the economic analysis of packer revenue for Improvest carcasses. These data provided the foundation for determining differences in the primal value of IC and PC barrow carcasses. Corresponding price data for pork cutouts were obtained from USDA daily pork cutout and primal values (USDA, USDA Market News, 2017). Historical pricing figures can be verified using the USDA mandatory reporting data mart application (USDA, LMR Date Mart, 2017). Within this application, all pricing is on a century weight basis (\$/100 lbs of product) and the value of each cutout was provided as value per lbs. Therefore, pork cutout weights were

multiplied by the corresponding cutout price and converted to value per kg. To provide a fair comparison of the added value of Improvest to packers, equal carcass weights for IC and PC barrows were used. To address fluctuation in pricing structures, a 5 year average of primal prices (2011 to 2015) was used for an average value calculation with 2 other scenarios during that time period highlighting the best (2014) and worst (2015) overall pricing for a single year.

Statistical Analyses

Data were analyzed using 2 different analysis strategies to address the 2 objectives of the study. The first objective was to evaluate the average effect of immunological castration on carcass value, cutability, belly quality, and loin quality compared with physical castration. The second objective was to assess the effects of slaughtering immunologically castrated barrows at different hot carcass weights.

Data sets were analyzed using the MIXED procedure in SAS (SAS Inst. Inc., Cary, NC). The model for comparing IC barrow carcasses with PC barrow carcasses included fixed effects of castration method with treatment means from each study as the experimental unit. Study was included as a random variable to account for differences in the production factors evaluated. To assess the effects of HCW on IC barrow carcasses, the model included hot carcass weight category as a fixed effect. Similarly, treatment means served as the experimental unit and study was included as a random effect. Least square means were separated using PDIFF option with a Tukey-Kramer adjustment for multiple comparisons. Differences in means were determined significant at $P \leq 0.05$. For error reporting of all evaluated variables, standard error of the difference (SED) was used instead of standard error of the mean to limit the influence of very large and very small studies on the overall results.

RESULTS AND DISCUSSION

The majority of studies comparing IC and PC barrows were ended at a constant age for comparison of different lengths of time after second dose of Improvest (Boler et al., 2012; Tavárez et al., 2014; Tavárez et al., 2016). Although ending live weights (ELW) of IC barrows were not statistically different ($P = 0.13$) from PC barrows, the ELW of IC barrows was 3.12 kg heavier (129.21 vs. 126.09 kg) than PC barrows. Hot carcass weights were not different ($P = 0.99$) between IC and PC barrows (96.26 vs. 96.25 kg). Dressing percentage of PC barrows was 1.9% units greater than IC barrows. This supports the numerical differences in ELW and

Table 1. Average fixed effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC)] on whole and trimmed primal cut-out values from a summary of previously reported data¹

| Item | IC | PC | Effect IC- PC | 95% CI | SED | P-value |
|---------------------------------------|-------|-------|---------------|---------------|------|---------|
| Studies, n | 7 | 6 | | | | |
| Carcasses, n | 511 | 320 | | | | |
| HCW, kg | 96.26 | 96.25 | 0.01 | (-3.27, 3.31) | 3.57 | 0.99 |
| Chilled side wt, kg | 46.22 | 46.19 | 0.03 | (-1.97, 2.03) | 2.15 | 0.98 |
| Estimated lean, % | 53.18 | 52.60 | 0.58 | (-0.40, 1.55) | 0.47 | 0.29 |
| Lean cutting yield, % ² | 70.89 | 69.50 | 1.39 | (0.88, 1.90) | 0.24 | < 0.01 |
| Carcass cutting yield, % ³ | 86.80 | 85.56 | 1.24 | (0.62, 1.85) | 0.31 | 0.02 |
| Whole ham, kg | 11.49 | 11.38 | 0.11 | (-0.26, 0.50) | 0.41 | 0.56 |
| % chilled side wt | 24.67 | 24.43 | 0.24 | (-0.23, 0.71) | 0.23 | 0.34 |
| Trimmed ham, kg | 9.85 | 9.56 | 0.29 | (-0.02, 0.60) | 0.33 | 0.11 |
| % chilled side wt | 21.36 | 20.74 | 0.62 | (0.13, 1.12) | 0.24 | 0.05 |
| Trimmed loin, kg | 10.65 | 10.47 | 0.18 | (-0.23, 0.60) | 0.48 | 0.40 |
| % chilled side wt | 22.19 | 21.86 | 0.33 | (-0.11, 0.78) | 0.22 | 0.19 |
| Boston butt, kg | 4.21 | 4.02 | 0.19 | (0.03, 0.36) | 0.18 | 0.05 |
| % chilled side wt | 9.14 | 8.69 | 0.45 | (0.19, 0.69) | 0.12 | 0.01 |
| Picnic shoulder, kg | 5.11 | 4.93 | 0.18 | (-0.06, 0.42) | 0.26 | 0.17 |
| % chilled side wt | 10.76 | 10.38 | 0.38 | (0.14, 0.63) | 0.12 | 0.02 |
| Spareribs, kg | 1.79 | 1.71 | 0.08 | (-0.03, 0.18) | 0.11 | 0.18 |
| % chilled side wt | 3.71 | 3.59 | 0.12 | (0.00, 0.24) | 0.06 | 0.10 |
| Natural fall belly, kg | 7.58 | 7.69 | -0.11 | (-0.39, 0.17) | 0.31 | 0.45 |
| % chilled side wt | 15.50 | 15.80 | -0.30 | (-0.61, 0.01) | 0.15 | 0.10 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014).

²Lean cutting yield = [(whole ham + trimmed loin + Boston butt + picnic + spareribs)/chilled side wt] × 100.

³Carcass cutting yield = [(lean cutting yield components + natural fall belly)/chilled side wt] × 100.

lack of difference in HCW observed in this review and previous studies, with dressing percentage differences likely attributable to increased testicle, reproductive tract and intestinal weights of IC barrows compared with PC barrows (Boler et al., 2014).

Whole and Trimmed Primal Yield

Immunologically castrated barrows exhibited a 1.39% unit advantage ($P < 0.0001$; SED 0.30) over PC barrows in lean cuts (LCY). When differences in belly yield were accounted for, IC barrows still displayed a 1.24% unit improvement ($P < 0.001$) in carcass cutting yield compared with PC barrows (Table 1). Overall, the average effect of immunological castration was representative of the individual studies included in the summary with differences attributable to study experimental factors. In control-fed (no DDGS) IC and PC barrows slaughtered 5 wk after second dose of Improvest, Tavárez et al. (2014) reported a magnitude of difference in bone-in carcass cutting yield of 2.54% units. However, this magnitude of difference decreased considerably (0.32% units) when barrows were fed 30% DDGS and slaughtered after longer intervals (7 wk) between second dose of Improvest and slaughter (Tavárez et al., 2014). Lowe et al. (2014) reported control-fed (no RAC) IC barrows demon-

strated similar cutability to RAC-fed PC barrows. Furthermore, Lowe et al. (2014) reported RAC-fed IC barrows had greater carcass cutting yields than RAC-fed PC barrows, suggesting additive effects of the RAC and Improvest technologies. Lowe et al. (2014) reported carcass cutout data as a percentage of HCW by multiplying the weight of cuts by 2 and dividing by the HCW. Although the total percentages reported in that study are less than reported in this review, the overall magnitude of differences are still representative of the published literature.

Trimmed ham (+ 0.62% units; $P = 0.01$), bone-in Boston butt (+ 0.45% units; $P < 0.001$), and bone-in picnic (+ 0.39% units; $P < 0.01$) of IC barrows made up a greater percentage of side weight than PC barrows. Although not statistically significant, IC barrows also exhibited an advantage in whole ham (+ 0.24% units; $P = 0.30$), trimmed loin (+ 0.33% units; $P = 0.13$), and sparerib yield (+ 0.12% units; $P = 0.06$) compared with PC barrows. Cutability advantages of IC barrows were amplified when comparing the magnitude of difference in trimmed versus whole (subcutaneous fat included) primals. Trimmed hams of IC barrows comprised a greater ($P < 0.0001$) percentage of the whole ham than PC barrows (86.05% vs. 84.37%) likely a result of decreased fat trim. This finding is in line with previous studies demonstrating compositional differ-

Table 2. Average fixed effects of whole and trimmed primals weights of carcasses from immunologically castrated barrows categorized by hot carcass weight¹

| Item | Hot carcass weight, kg | | | SED ² | P-value |
|---------------------------------------|------------------------|-------------------------|---------------------|------------------|----------|
| | Light (< 90.9 kg) | Average (90.9- 97.7 kg) | Heavy (> 97.7 kg) | | |
| Studies, n | 2 | 3 | 4 | | |
| Carcasses, n | 108 | 225 | 178 | | |
| HCW, kg | 88.07 ^a | 92.54 ^b | 102.66 ^c | 0.95 | < 0.0001 |
| Chilled side wt, kg | 43.05 ^a | 44.49 ^b | 50.10 ^c | 0.74 | < 0.0001 |
| Estimated lean, % | 54.77 ^b | 55.78 ^b | 50.91 ^a | 0.91 | < 0.001 |
| Lean cutting yield, % ³ | 71.56 ^a | 71.15 ^{ab} | 70.33 ^b | 0.34 | < 0.01 |
| Carcass cutting yield, % ⁴ | 87.44 ^a | 87.51 ^a | 85.98 ^b | 0.51 | < 0.01 |
| Whole ham, kg | 10.51 ^a | 10.93 ^b | 11.97 ^c | 0.20 | < 0.0001 |
| % chilled side wt | 24.60 ^a | 25.58 ^b | 23.95 ^a | 0.51 | < 0.01 |
| Trimmed ham, kg | 9.13 ^a | 9.65 ^b | 10.14 ^c | 0.16 | < 0.001 |
| % chilled side wt | 21.56 ^b | 22.51 ^a | 20.47 ^c | 0.52 | < 0.01 |
| Trimmed loin, kg | 9.70 ^a | 10.29 ^a | 11.13 ^b | 0.32 | < 0.001 |
| % chilled side wt | 22.07 ^a | 22.97 ^b | 21.69 ^a | 0.53 | 0.02 |
| Boston butt, kg | 3.83 ^a | 4.24 ^b | 4.26 ^b | 0.12 | < 0.001 |
| % chilled side wt | 9.15 ^b | 9.86 ^a | 8.62 ^c | 0.15 | < 0.0001 |
| Picnic shoulder, kg | 4.62 ^a | 4.62 ^a | 5.54 ^b | 0.13 | < 0.0001 |
| % chilled side wt | 10.49 | 10.78 | 10.85 | 0.25 | 0.12 |
| Spareribs, kg | 1.58 ^a | 1.57 ^a | 1.90 ^b | 0.09 | < 0.01 |
| % chilled side wt | 3.74 | 3.62 | 3.76 | 0.19 | 0.76 |
| Natural fall belly, kg | 6.87 ^a | 7.38 ^b | 7.81 ^b | 0.25 | < 0.001 |
| % chilled side wt | 15.29 ^a | 16.00 ^b | 15.22 ^a | 0.34 | < 0.01 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014).

²Greatest reported.

³Lean cutting yield = [(whole ham + trimmed loin + Boston butt + picnic + spareribs)/chilled side wt] × 100.

⁴Carcass cutting yield = [(lean cutting yield components + natural fall belly)/chilled side wt] × 100.

^{a-c}Means within row lacking common superscripts differ ($P < 0.05$).

ences in the ham between IC and PC barrows at equal carcass weights (Boler et al., 2012). Conversely, natural fall bellies of PC barrows (15.80%) comprised a greater ($P = 0.05$) percentage of side weight than those from IC barrows (15.50%).

Both carcass and lean cutting yield of IC barrows decreased as HCW increased, with IC barrows slaughtered at light and average HCW having a 1.46% unit advantage ($P < 0.01$) in carcass cutting yield compared with heavy HCW IC barrows (Table 2). This advantage is further illustrated by the substantial reduction (-3.86% units; $P < 0.001$) in estimated lean percentage of heavy HCW IC barrows compared with light and average HCW IC barrows. Despite these reductions in cutting yield, when pooled across HCW groups, IC barrows still exhibited a greater carcass and lean cutting yield than PC barrows (Table 1). The reduction in the yield of trimmed cuts from heavy IC barrows compared with light IC barrows agrees with other observations that as the interval between second dose of Improvest and slaughter increased, IC barrows got older and heavier in most studies (Boler et al., 2012; Tavárez et al., 2014). Therefore added carcass weight may be a result of increased fat deposition as

IC barrows transition compositionally toward PC barrows. Tavárez et al. (2016) did not show differences in HCW of IC barrows slaughtered at different lengths after second dose of Improvest because the objective of that study was to show effects of age and time after second dose of Improvest, independent of carcass weight. Similarly, in a study designed to mimic commercial production practices with pigs selected for slaughter on ending live weight and segregated into 3 marketing groups, Lowe et al. (2014) reported both IC and PC barrows slaughtered in the second and third (barn-dump) marketing groups had reduced lean cutting yields compared with barrows slaughtered in the first marketing group.

Not surprisingly, the weight of all primals from IC barrows increased as HCW increased. However, when primals were expressed as a percentage of side weight, it appears that Improvest influenced the allometric growth rate of the primals in relation to growth rate of the entire pig. Although trimmed ham weight and HCW of IC barrows increased concurrently, the percentage of trimmed ham decreased as HCW increased ($P = 0.01$), possibly due to the increased fat deposition of heavier IC barrows. Findings of Tavárez et al.

Table 3. Average fixed effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC)] on ham cut-out values from a summary of previously reported data^{1,2}

| Item | IC | PC | Effect IC- PC | 95% CI | SED | P-value |
|-------------------|-------|-------|---------------|---------------|------|---------|
| Inside, kg | 1.78 | 1.72 | 0.06 | (-0.01, 0.11) | 0.06 | 0.13 |
| % chilled side wt | 3.74 | 3.63 | 0.11 | (0.02, 0.18) | 0.04 | 0.04 |
| % trimmed ham | 17.96 | 17.97 | -0.01 | (-0.24, 0.22) | 0.11 | 0.91 |
| Outside, kg | 2.46 | 2.36 | 0.10 | (0.01, 0.19) | 0.09 | 0.06 |
| % chilled side wt | 5.18 | 4.98 | 0.20 | (0.10, 0.31) | 0.05 | < 0.01 |
| % trimmed ham | 24.91 | 24.60 | 0.31 | (0.02, 0.60) | 0.14 | 0.09 |
| Knuckle, kg | 1.40 | 1.35 | 0.05 | (0.00, 0.10) | 0.02 | 0.03 |
| % chilled side wt | 2.95 | 2.84 | 0.11 | (0.06, 0.17) | 0.03 | < 0.001 |
| % trimmed ham | 14.18 | 14.05 | 0.13 | (-0.08, 0.35) | 0.10 | 0.20 |
| Lite butt, kg | 0.37 | 0.33 | 0.04 | (0.02, 0.06) | 0.01 | < 0.001 |
| % chilled side wt | 0.77 | 0.69 | 0.08 | (0.02, 0.12) | 0.02 | < 0.01 |
| % trimmed ham | 3.73 | 3.43 | 0.30 | (0.05, 0.54) | 0.12 | 0.02 |
| Inside shank, kg | 0.72 | 0.68 | 0.04 | (0.01, 0.06) | 0.01 | < 0.01 |
| % chilled side wt | 1.54 | 1.46 | 0.08 | (0.03, 0.13) | 0.02 | < 0.01 |
| % trimmed ham | 7.40 | 7.22 | 0.18 | (0.03, 0.33) | 0.07 | 0.02 |
| Ham bones, kg | 1.29 | 1.22 | 0.07 | (0.01, 0.12) | 0.03 | 0.03 |
| % chilled side wt | 2.68 | 2.56 | 0.12 | (0.03, 0.20) | 0.04 | 0.01 |
| % trimmed ham | 13.19 | 12.90 | 0.29 | (0.00, 0.59) | 0.14 | 0.05 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014).

²Outer shank not included.

Table 4. Average fixed effects of ham carcass cutout from immunologically castrated barrows categorized by hot carcass weight^{1,2}

| Item | Hot carcass weight, kg | | | SED ³ | P-value |
|-------------------|------------------------|------------------------|-------------------|------------------|----------|
| | Light (< 90.9 kg) | Average (90.9-97.7 kg) | Heavy (> 97.7 kg) | | |
| Inside, kg | 1.65 ^a | 1.70 ^a | 1.85 ^b | 0.05 | < 0.001 |
| % chilled side wt | 3.83 | 3.79 | 3.68 | 0.12 | 0.22 |
| % trimmed ham | 17.95 | 17.75 | 18.08 | 0.43 | 0.75 |
| Outside, kg | 2.24 ^a | 2.34 ^a | 2.57 ^b | 0.07 | < 0.001 |
| % chilled side wt | 5.23 | 5.22 | 5.11 | 0.14 | 0.48 |
| % trimmed ham | 24.49 | 24.73 | 24.96 | 0.39 | 0.16 |
| Knuckle, kg | 1.27 ^a | 1.37 ^b | 1.45 ^b | 0.04 | < 0.0001 |
| % chilled side wt | 2.98 | 3.07 | 2.88 | 0.08 | 0.09 |
| % trimmed ham | 13.89 | 14.33 | 14.12 | 0.34 | 0.32 |
| Lite butt, kg | 0.37 | 0.33 | 0.38 | 0.04 | 0.43 |
| % chilled side wt | 0.81 | 0.71 | 0.78 | 0.07 | 0.30 |
| % trimmed ham | 4.06 | 3.46 | 3.73 | 0.39 | 0.20 |
| Inside shank, kg | 0.68 | 0.74 | 0.72 | 0.03 | 0.06 |
| % chilled side wt | 1.57 ^a | 1.65 ^a | 1.46 ^b | 0.07 | 0.03 |
| % trimmed ham | 7.43 | 7.75 | 7.15 | 0.24 | 0.09 |
| Ham bones, kg | 1.19 ^a | – | 1.32 ^b | 0.02 | < 0.01 |
| % chilled side wt | 2.76 | – | 2.66 | 0.07 | 0.19 |
| % trimmed ham | 13.29 | – | 13.18 | 0.22 | 0.61 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014).

²Outer shank not included.

³Greatest reported.

^{a,b}Means within row lacking common superscripts differ ($P < 0.05$).

(2014) support this observation, showing an increase of approximately 6 mm in 10th–rib back fat depth of IC barrows slaughtered at heavy (102 kg) HCW compared with light (87 kg) HCW.

Subprimal Yield

Ham Subprimal Yields. Trimmed hams of IC barrows comprised a greater percentage ($P < 0.0001$) of whole ham weight than PC barrows, indicating less required fat trim. Given the increase ($P = 0.01$) in percentage of trimmed ham of IC barrows (21.36%) compared with PC barrows (20.74%), all ham component pieces for IC barrows also made up a greater ($P \leq 0.01$) percentage of side weight than PC barrows. These differences are further amplified when component pieces are evaluated as a percentage of trimmed ham weight (Table 3). The outside, lite butt, shank and ham bones of IC barrows all made up a greater percentage of trimmed ham compared with ham components from PC barrows.

The weight of insides, outsides, and knuckles all increased ($P < 0.001$) when IC barrows were marketed at heavier weights (Table 4). However, inside and outside hams comprised a lesser proportion of side weight, numerically, as HCW of IC barrows increased.

Loin Subprimal Yields. The Canadian back loin (+ 0.28% units; $P = 0.02$), tenderloin (+ 0.04% units; $P < 0.01$), and sirloin (+ 0.07% units; $P < 0.01$) of IC barrows each comprised a greater percentage of side

Table 5. Average fixed effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC)] on loin cut-out values from a summary of previously reported data^{1,2}

| Item | IC | PC | Effect IC- PC | 95% CI | SED | P-value |
|-------------------|-------|-------|---------------|----------------|------|---------|
| Fat back, kg | 2.67 | 3.05 | -0.38 | (-0.74, -0.02) | 0.14 | 0.04 |
| % chilled side wt | 5.39 | 6.11 | -0.72 | (-1.36, -0.09) | 0.25 | 0.03 |
| Canadian back, kg | 3.73 | 3.60 | 0.13 | (-0.02, 0.28) | 0.07 | 0.09 |
| % chilled side wt | 8.02 | 7.74 | 0.28 | (0.05, 0.50) | 0.11 | 0.02 |
| % trimmed loin | 34.90 | 34.28 | 0.62 | (0.05, 1.20) | 0.29 | 0.04 |
| Tenderloin, kg | 0.48 | 0.46 | 0.02 | (-0.01, 0.04) | 0.01 | 0.18 |
| % chilled side wt | 1.02 | 0.98 | 0.04 | (0.01, 0.05) | 0.01 | < 0.01 |
| % trimmed loin | 4.51 | 4.43 | 0.08 | (-0.04, 0.19) | 0.06 | 0.18 |
| Sirloin, kg | 0.85 | 0.82 | 0.03 | (-0.01, 0.08) | 0.02 | 0.13 |
| % chilled side wt | 1.80 | 1.73 | 0.07 | (0.02, 0.12) | 0.02 | < 0.01 |
| % trimmed loin | 7.99 | 7.83 | 0.16 | (-0.04, 0.35) | 0.09 | 0.11 |
| Backribs, kg | 0.78 | 0.78 | 0.00 | (-0.05, 0.04) | 0.02 | 0.91 |
| % chilled side wt | 1.63 | 1.64 | -0.01 | (-0.06, 0.04) | 0.02 | 0.79 |
| % trimmed loin | 7.38 | 7.51 | -0.13 | (-0.34, 0.09) | 0.10 | 0.23 |
| Backbones, kg | 1.96 | 1.93 | 0.03 | (-0.09, 0.15) | 0.05 | 0.63 |
| % chilled side wt | 4.02 | 3.96 | 0.06 | (-0.08, 0.20) | 0.06 | 0.36 |
| % trimmed loin | 18.44 | 18.37 | 0.07 | (-0.40, 0.54) | 0.22 | 0.76 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014).

²Excluded minor pieces include hip bone, blade bone, and minor trim.

weight than the same cuts from PC barrows (Table 5). Canadian back loins of IC barrows yielded an even greater (0.62% unit; $P = 0.04$) advantage over PC barrows when evaluated as a percentage of trimmed loin. Improvements in lean cuts from the loin are further validated by the reduced ($P = 0.03$) percentage of fat back from IC barrows (5.39%) compared with PC barrows (6.11%). No differences were found in the percentage of backrib and backbone between IC and PC barrows.

Canadian back, tenderloin, sirloin and backrib weights increased ($P \leq 0.03$) as IC barrows were marketed at heavier weights (Table 6). Both Canadian back loins and sirloins of average HCW IC barrows made up a greater percentage of side weight than light or heavy HCW IC barrows.

Shoulder Subprimal Yields. As a percentage of side weight, boneless Boston butt (+ 0.39% units; $P < 0.001$), boneless picnic (+ 0.16% units; $P = 0.01$), and cushion (triceps brachii, + 0.10% units; $P = 0.02$) were greater for IC barrows than PC barrows (Table 7). Interestingly, the picnic bones of IC barrows were 0.10% units greater than PC barrows as a percentage of side weight ($P \leq 0.01$), but there was no difference in neck bone percentage. Both jowls and clear plates made up a lesser ($P \leq 0.02$) percentage of side weight for IC barrows than PC barrows, similar to the effects observed in other high fat carcass components.

As IC barrows were marketed at heavier weights, weights of bone-in Boston butt, and bone-in picnic increased linearly ($P < 0.0001$). Picnic shoulder components (boneless picnic and cushion) increased in weight

Table 6. Average fixed effects of loin carcass cutout values from immunologically castrated barrows categorized by hot carcass weight^{1,2}

| Item | Hot carcass weight, kg | | | SED ³ | P-value |
|-------------------|------------------------|-------------------------------|----------------------|------------------|----------|
| | Light (< 90.9 kg) | Average (90.9- 97.7 kg) | Heavy (> 97.7 kg) | | |
| Fat back, kg | – | – | – | – | – |
| % chilled side wt | – | – | – | – | – |
| Canadian back, kg | 3.41 ^a | 3.55 ^a | 3.90 ^b | 0.13 | < 0.01 |
| % chilled side wt | 7.97 ^a | 8.38 ^b | 7.76 ^a | 0.26 | 0.03 |
| % trimmed loin | 34.85 | 34.01 | 35.19 | 0.84 | 0.41 |
| Tenderloin, kg | 0.42 ^a | 0.45 ^b | 0.51 ^c | 0.01 | < 0.0001 |
| % chilled side wt | 1.00 | 1.02 | 1.02 | 0.05 | 0.74 |
| % trimmed loin | 4.38 | 4.49 | 4.58 | 0.19 | 0.28 |
| Sirloin, kg | 0.74 ^a | 0.88 ^b | 0.87 ^b | 0.04 | < 0.001 |
| % chilled side wt | 1.77 ^a | 1.99 ^b | 1.72 ^a | 0.06 | < 0.01 |
| % trimmed loin | 7.67 ^a | 8.57 ^b | 7.79 ^{ab} | 0.21 | < 0.01 |
| Backribs, kg | 0.73 ^a | 0.70 ^a | 0.83 ^b | 0.06 | 0.03 |
| % chilled side wt | 1.72 | 1.57 | 1.66 | 0.12 | 0.35 |
| % trimmed loin | 7.66 | 6.77 | 7.65 | 0.66 | 0.41 |
| Backbones, kg | 1.79 ^a | – | 2.00 ^b | 0.06 | 0.02 |
| % chilled side wt | 4.33 | – | 4.05 | 0.14 | 0.08 |
| % trimmed loin | 18.84 | – | 18.43 | 0.54 | 0.47 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014).

²Excluded minor pieces, including hip bone, blade bone, and minor trim.

³Greatest reported.

^{a-c}Means within row lacking common superscripts differ ($P < 0.05$).

Table 7. Average fixed effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC)] on shoulder cut-out values from a summary of previously reported data^{1,2}

| Item | IC | PC | Effect IC- PC | 95% CI | SED | P-value |
|----------------------------------|-------|-------|---------------|----------------|------|---------|
| Boneless Boston butt, kg | 3.89 | 3.71 | 0.18 | (0.03, 0.34) | 0.07 | 0.02 |
| % chilled side wt | 8.15 | 7.76 | 0.39 | (0.19, 0.59) | 0.09 | < 0.001 |
| % bone-in Boston butt | 92.26 | 92.31 | -0.05 | (-0.45, 0.35) | 0.19 | 0.79 |
| Boneless picnic, kg ² | 3.85 | 3.74 | 0.11 | (-0.04, 0.27) | 0.08 | 0.15 |
| % chilled side wt | 8.09 | 7.93 | 0.16 | (0.04, 0.29) | 0.06 | 0.01 |
| % bone-in picnic | 75.37 | 75.88 | -0.51 | (-1.64, 0.61) | 0.55 | 0.36 |
| Cushion, kg | 1.15 | 1.11 | 0.04 | (0.00, 0.07) | 0.01 | 0.02 |
| % chilled side wt | 2.42 | 2.31 | 0.11 | (0.02, 0.19) | 0.04 | 0.02 |
| % bone-in picnic | 22.37 | 22.49 | -0.12 | (-0.99, 0.72) | 0.41 | 0.75 |
| Jowl, kg | 1.25 | 1.34 | -0.09 | (-0.19, 0.00) | 0.05 | 0.06 |
| % chilled side wt | 2.61 | 2.81 | -0.20 | (-0.32, -0.08) | 0.06 | < 0.01 |
| Neck bones, kg | 1.02 | 1.00 | 0.02 | (-0.06, 0.10) | 0.04 | 0.63 |
| % chilled side wt | 2.09 | 2.05 | 0.04 | (-0.03, 0.11) | 0.03 | 0.25 |
| Clear plate, kg | 0.95 | 1.03 | -0.08 | (-0.20, 0.03) | 0.05 | 0.15 |
| % chilled side wt | 1.89 | 2.07 | -0.18 | (-0.33, -0.04) | 0.07 | 0.02 |
| Picnic bones, kg | 0.91 | 0.85 | 0.06 | (-0.02, 0.14) | 0.04 | 0.15 |
| % chilled side wt | 1.89 | 1.79 | 0.10 | (0.05, 0.16) | 0.03 | < 0.01 |
| % bone-in picnic | 17.33 | 16.81 | 0.52 | (-0.11, 1.17) | 0.30 | 0.10 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014)

²Bnls picnic includes cushion.

Table 8. Average fixed effects of shoulder carcass cut-out values from immunologically castrated barrows categorized by hot carcass weight¹

| Item | Hot carcass weight, kg | | | SED ² | P-value |
|----------------------------------|------------------------|-------------------------|--------------------|------------------|----------|
| | Light (< 90.9 kg) | Average (90.9- 97.7 kg) | Heavy (> 97.7 kg) | | |
| Boneless Boston butt, kg | 3.55 ^a | 3.90 ^b | 3.94 ^b | 0.13 | < 0.01 |
| % chilled side wt | 8.29 ^b | 8.73 ^c | 7.82 ^a | 0.19 | < 0.01 |
| % bone-in Boston butt | 92.41 | 92.11 | 92.43 | 0.45 | 0.75 |
| Boneless picnic, kg ³ | 3.52 ^a | 3.53 ^a | 4.15 ^b | 0.09 | < 0.0001 |
| % chilled side wt | 8.13 | 7.89 | 8.23 | 0.16 | 0.15 |
| % bone-in picnic | 75.81 | 76.59 | 74.78 | 0.75 | 0.08 |
| Cushion, kg | 1.11 | 1.12 | 1.18 | 0.06 | 0.27 |
| % chilled side wt | 2.55 | 2.48 | 2.37 | 0.17 | 0.21 |
| % bone-in picnic | 23.75 ^a | 23.95 ^{ab} | 21.33 ^b | 1.37 | 0.04 |
| Jowl, kg | 1.10 ^a | 1.06 ^a | 1.39 ^b | 0.06 | < 0.0001 |
| % chilled side wt | 2.55 ^a | 2.36 ^a | 2.76 ^b | 0.12 | 0.02 |
| Neck bones, kg | 0.86 ^a | – | 1.04 ^b | 0.03 | < 0.001 |
| % chilled side wt | 2.08 | – | 2.10 | 0.06 | 0.70 |
| Clear plate, kg | 0.73 ^a | – | 0.97 ^b | 0.05 | < 0.01 |
| % chilled side wt | 1.75 | – | 1.95 | 0.09 | 0.08 |
| Picnic bones, kg | 0.75 ^a | – | 0.95 ^b | 0.02 | < 0.0001 |
| % chilled side wt | 1.80 ^a | – | 1.92 ^b | 0.14 | < 0.01 |
| % bone-in picnic | 16.82 ^a | – | 17.47 ^b | 0.17 | < 0.01 |

¹Sources include Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014), and Harris (2014).

²Greatest reported.

³Bnls picnic includes cushion.

^{a-c}Means within row lacking common superscripts differ ($P < 0.05$).

as HCW of IC barrows increased, comprising a numerically lesser percentage of bone-in picnics. This is likely a result of a concomitant increase in picnic bone percentage. Of the primary fat components from the shoulder, jowls comprised a greater ($P = 0.02$) percentage of side weight and clear plate weight increased ($P < 0.01$) as IC barrows were marketed at heavier weights (Table 8).

Belly Quality Attributes

Because bellies are currently one of the most valuable primal pieces of pork carcasses in the U.S., it is imperative to understand the effects of Improvest on belly quality attributes. One disadvantage associated with increased leanness in pigs is a potential for wider, thinner bellies (Boler et al., 2012; Kyle et al., 2014). Meat quality characteristics of IC barrows are often compared with both PC barrows and gilts. Two studies (Boler et al., 2014; Lowe et al., 2016b) meeting the criteria for inclusion included all 3 sex classes (IC barrows, PC barrows, and gilts) and were included in the belly and loin quality analyses.

Natural fall bellies of IC barrows (15.50%) comprised a lesser ($P = 0.05$) percentage of chilled side weight than bellies from PC barrows (15.80%). No difference was observed in belly width or iodine value among IC barrows, PC barrows, and gilts (Table 9). No difference in belly length was observed either. Bellies of IC barrows were thinner than PC barrows, but thicker than gilts (3.55 vs. 3.83 & 3.22 cm respectively; $P < 0.0001$).

Table 9. Average fixed effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC) and gilts] on belly quality attributes¹

| Item | IC | Gilt | PC | SED ² | P-value |
|---------------------------------|-------------------|-------------------|-------------------|------------------|----------|
| Length, cm | 63.55 | 62.93 | 63.35 | 0.93 | 0.74 |
| Width, cm | 24.53 | 24.28 | 23.93 | 0.98 | 0.11 |
| Thickness, cm | 3.55 ^b | 3.23 ^a | 3.83 ^c | 1.43 | < 0.0001 |
| Belly iodine value ³ | 65.27 | 68.35 | 65.02 | 3.24 | 0.59 |

¹Sources include Boler et al. (2011b, 2012), Kyle et al. (2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), and Harris (2014).

²Greatest reported.

³Calculated as IV value = C16:1 × (0.95) + C18:1 × (0.86) + C18:2 (1.732) + C18:3 × (2.616) + C20:1 × (0.785) + C22:1 × (0.723) (AOCS, 1998).

^{a-c}Means within row lacking common superscripts differ ($P < 0.05$).

Table 10. Average fixed effects of belly quality from immunologically castrated barrows categorized by hot carcass weight¹

| Item | Hot carcass weight, kg | | | SED ² | P-value |
|---------------------------------|------------------------|------------------------|-------------------|------------------|----------|
| | Light (< 90.9 kg) | Average (90.9-97.7 kg) | Heavy (> 97.7 kg) | | |
| Length, cm | 62.35 | 62.25 | 64.65 | 0.85 | 0.01 |
| Width, cm | 24.33 | 23.80 | 25.03 | 0.63 | 0.15 |
| Thickness, cm ³ | 3.25 ^a | 3.33 ^a | 3.80 ^b | 0.08 | < 0.0001 |
| Belly iodine value ⁴ | 68.10 | 64.39 | 64.46 | 2.05 | 0.16 |

¹Sources include Boler et al. (2011b, 2012), Kyle et al. (2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), and Harris (2014).

²Greatest reported.

³Thickness is the average of 8 measurements collected along the belly, where location 1 to 4 is from the anterior to posterior position of the dorsal edge and location 5 to 8 is from the anterior to posterior position of the ventral edge.

⁴Calculated as IV value = C16:1 × (0.95) + C18:1 × (0.86) + C18:2 (1.732) + C18:3 × (2.616) + C20:1 × (0.785) + C22:1 × (0.723) (AOCS, 1998).

^{a,b}Means within row lacking common superscripts differ ($P < 0.05$).

Table 11. Average fixed effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC)] on belly processing attributes¹

| Item | IC | PC | Effect IC- PC | SED | P-value |
|------------------|-------|-------|---------------|------|---------|
| Initial wt, kg | 5.45 | 5.55 | -0.10 | 0.12 | 0.44 |
| Pump wt, kg | 6.15 | 6.22 | -0.07 | 0.14 | 0.62 |
| Pump uptake, % | 12.76 | 12.12 | 0.64 | 0.32 | 0.06 |
| Cooked wt, kg | 5.51 | 5.65 | -0.14 | 0.13 | 0.32 |
| Slicing Yield, % | 84.24 | 87.66 | -3.42 | 0.81 | < 0.001 |

¹Sources include Boler et al. (2011b, 2012), Kyle et al. (2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), and Harris (2014).

Although belly length of IC barrows increased linearly ($P = 0.01$) with HCW, HCW had no effect on belly width (Table 10). However, belly thickness did increase ($P < 0.0001$) as IC barrows were marketed at heavier weights. Iodine value was numerically less for IC barrows in the average (64.39 units) or heavy (64.46 units) HCW category compared with IC barrows in the light (68.10 units) HCW category.

Processing Attributes

No processing differences were observed between IC and PC barrows for initial (green) weight, pump weight, pump uptake, and cooked weight of bellies (Table 11). When expressed as a percentage of cooked weight, commercial slicing yield of bacon from IC barrows decreased ($P < 0.001$) 3.43% compared with commercial slicing yield of bacon from PC barrows.

Because there were no studies that evaluated bacon slicing yield in which IC barrows had a HCW in the average (90.9 to 97.7 kg) category, slicing yield was only compared between IC and PC barrows in the light (< 90.9 kg) and heavy (> 97.7 kg) HCW categories. Bellies from PC barrows had greater ($P \leq 0.01$) bacon slicing yield than bellies from IC barrows in both HCW categories. No slicing yield differences ($P = 0.26$) were observed between IC barrows in the light and heavy HCW categories. When effect of weight was eliminated by selecting pigs at equal ending live weights, Kyle et al. (2014) reported IC barrows had decreased slicing yields compared with PC barrows and gilts.

In the light HCW category, PC barrows had a 4.4% unit advantage ($P < 0.01$) in bacon slicability compared with IC barrows. However, in the heavy HCW category, that advantage ($P = 0.01$) in slicing yield was reduced to 2.9% units. This translates to a 1.5% unit improvement in bacon slicing yield of IC barrows in the heavy HCW category compared with light HCW IC barrows (Fig. 1). This observation parallels the findings of other individual studies evaluating the effects of Improvest on belly quality and bacon slicing attributes of heavy weight pigs. In a study of the effects of time after second dose of Improvest and age at slaughter, Tavárez et al. (2016) reported no difference in bacon slicing yield of IC barrows compared with PC barrows and gilts when slaughtered at 24 wk of age and held to heavier weights (100 kg) representative of current U.S. marketing practices.

As HCW of IC barrows increased, bellies increased in initial (green) weight, pump weight, and cooked weight (Table 12). Because natural fall belly weight of IC barrows also increased with HCW, processing attribute findings are likely attributable to increased weight gain. Similarly, Tavárez et al. (2016) reported processing characteristics, in a population of heavy weight pigs, were most related to absolute weight of bellies. Hot carcass weight of IC barrows had no effect on pump uptake of bellies.

Loin Quality Attributes

Historically, loins have been the primal used to determine total carcass quality. Therefore it is important to evaluate loin quality parameters. The effect of

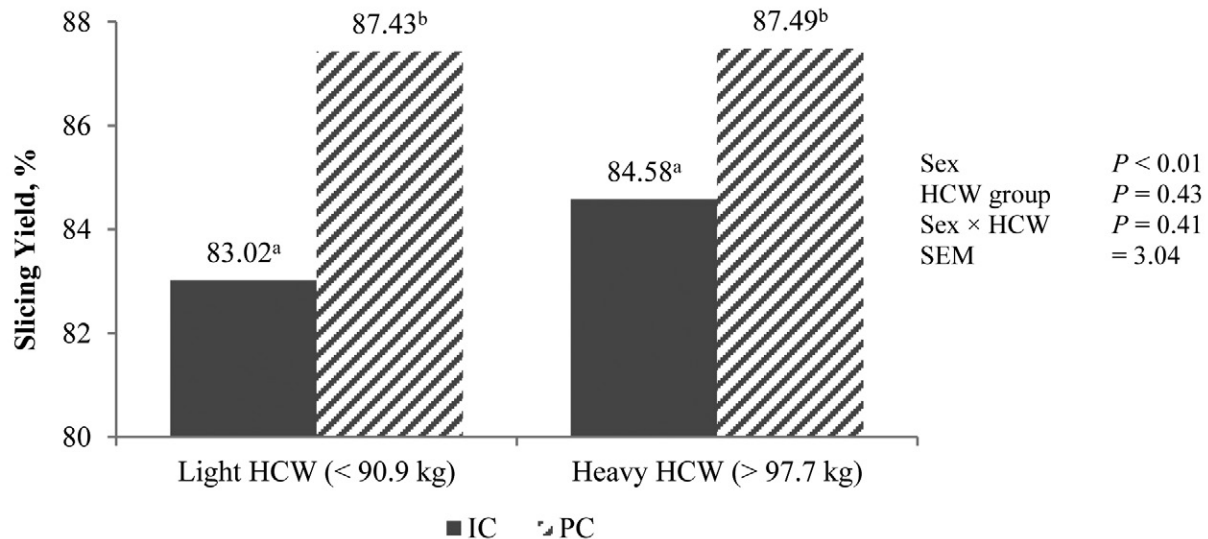


Figure 1. Effect of hot carcass weight on commercial bacon slicing yield of immunologically castrated (IC) barrows and physically castrated (PC) barrows. Data are depicted as least squared means \pm SEM, and means lacking common superscripts (a,b; indicating differences in sex and HCW) differ ($P < 0.05$).

Table 12. Average fixed effects of processing attributes of bellies from immunologically castrated barrows categorized by hot carcass weight¹

| Item | Hot carcass weight, kg | | | SED ² | P-value |
|----------------|------------------------|------------------------|-------------------|------------------|----------|
| | Light (< 90.9 kg) | Average (90.9-97.7 kg) | Heavy (> 97.7 kg) | | |
| Initial wt, kg | 4.90 ^a | 5.21 ^b | 5.76 ^c | 0.16 | < 0.0001 |
| Pump wt, kg | 5.55 ^a | 5.87 ^b | 6.51 ^c | 0.17 | < 0.0001 |
| Pump uptake, % | 13.11 | 12.67 | 13.17 | 0.62 | 0.69 |
| Cooked wt, kg | 4.92 ^a | 5.22 ^a | 5.86 ^b | 0.17 | < 0.0001 |

¹Sources include Boler et al. (2011b, 2012), Kyle et al. (2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), and Harris (2014).

²Greatest reported.

^{a-c}Means within row lacking common superscripts differ ($P < 0.05$).

Improvest on loin quality was one of the first meat quality attributes to be evaluated after Improvest was approved (Pauly et al., 2009; Batorek et al., 2012). Accordingly, there is a larger body of available literature. Subjective quality was evaluated using color, marbling, and firmness standards as set by the National Pork Producers Council (NPPC, 1991; 1999).

There were no differences in shear force (tenderness), cook loss percentage, ultimate pH, or instrumental color measurements between IC and PC barrows (Table 13). Loin chops from IC barrows were less marbled and less firm, subjectively, than those from PC barrows, but were similar to chops from gilts. Similarly, PC barrows had the greatest percentage ($P = 0.03$) of extractable lipid (2.39%). There were no differences ($P = 0.84$) in extractable lipid between IC barrows (2.01%) and gilts (2.08%). Although the moisture content of loins from IC barrows and gilts was greater than PC barrows, there was no difference in percent drip loss between IC and PC barrows.

Hot carcass weight had no impact ($P \geq 0.14$) on shear force, cook loss percentage, or drip loss of IC barrows. There were no instrumental color differences as HCW of IC barrows increased. However, loins tended ($P = 0.06$) to get darker (decreased L* value) as the HCW of IC barrows increased. As HCW increased among IC carcasses, loin chops became subjectively darker and more marbled (Table 14). Subjective marbling findings were confirmed as extractable lipid of loins increased ($P = 0.03$) with HCW. A concurrent reduction in IC barrow loin moisture occurred as HCW increased.

Estimated Value Proposition

By applying the average value of each cutout to a whole carcass basis and multiplying the result by the price per kg, a total dollar value for each primal was determined on a per carcass basis. This allowed for the comparison of carcass values between IC and PC barrows at equal carcass weights. Using prices averaged over a 5-yr period, the cutability advantage of IC barrow carcasses compared with PC barrow carcasses resulted in a \$3.08 increase in lean cuts value when HCW was held constant (Fig. 2). Bellies from IC barrows were thinner and had reduced bacon slicability compared with bellies of PC barrows. This resulted in a decreased value of \$0.64 per IC barrow carcass. When combined (\$3.08- \$0.64) these values resulted in an additional \$2.44 in carcass value of IC barrows compared with equal weight PC barrow carcasses (Table 15). Results from the 2 other pricing scenarios show that IC barrows had an increased value of \$3.13/carcass using the best year (2014) primal pricing and \$2.08/carcass increase using the worst year (2015) primal pricing compared with PC barrows.

Table 13. Average fixed effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC) and gilts] on loin quality¹

| Item | IC | Gilt | PC | Effect IC vs. | | SED ² | P-value |
|---------------------------------|--------------------|---------------------|--------------------|---------------|-------|------------------|---------|
| | | | | Gilt | PC | | |
| pH | 5.59 | 5.55 | 5.60 | -0.04 | 0.01 | 0.05 | 0.60 |
| Instrumental color ³ | | | | | | | |
| L* | 48.52 | 48.03 | 48.25 | -0.49 | -0.27 | 0.90 | 0.69 |
| a* | 6.89 | 6.75 | 7.13 | -0.14 | 0.24 | 0.46 | 0.31 |
| b* | 3.67 | 3.59 | 3.79 | -0.08 | 0.12 | 0.45 | 0.72 |
| Subjective quality ⁴ | | | | | | | |
| Color | 2.83 | 2.93 | 3.01 | 0.10 | 0.18 | 0.25 | 0.24 |
| Marbling | 1.74 ^a | 1.59 ^{ab} | 2.07 ^b | -0.15 | 0.33 | 0.22 | < 0.01 |
| Firmness | 2.52 ^a | 2.53 ^{ab} | 2.72 ^b | 0.01 | 0.20 | 0.14 | < 0.01 |
| Loin composition | | | | | | | |
| Moisture, % | 74.61 ^a | 74.33 ^{ab} | 74.12 ^b | -0.28 | -0.49 | 0.50 | 0.02 |
| Fat, % | 2.01 ^a | 2.08 ^{ab} | 2.39 ^b | 0.07 | 0.38 | 0.31 | 0.03 |
| Drip loss, % | 2.78 ^{ab} | 3.14 ^b | 2.56 ^a | 0.36 | -0.22 | 0.28 | 0.04 |
| Cook loss, % | 21.04 | 21.11 | 20.73 | 0.07 | -0.31 | 1.36 | 0.83 |
| WB Shear force, kg ⁵ | 2.92 | – | 2.91 | – | -0.01 | 0.08 | 0.82 |

¹Sources include Pauly et al. (2009), Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), Harris (2014), and Elsbernd et al. (2016).

²Greatest reported.

³Minolta Colorimeter, D65 illuminant. L*, greater value indicates a lighter color; a*, greater value indicates a redder color; b*, greater value indicates a more yellow color.

⁴Evaluated according to National Pork Producers Council standards for color and marbling (NPPC, 1999) and firmness (NPPC, 1991).

⁵Warner-Bratzler shear force was conducted on chops aged 14 to 21 d postmortem.

^{a,b}Means within row lacking common superscripts differ ($P < 0.05$).

Using the 5-yr primal pricing average, carcasses from IC barrows slaughtered within the average HCW category (90.9– 97.7 kg) had an added value of \$2.53 more per carcass compared with carcasses of IC barrows in the light HCW category. Using the best and worst case primal pricing scenarios, carcasses of IC barrows slaughtered within the average HCW category were worth up to \$3.10 more and as little as \$1.96 more than carcasses of IC barrows in the light HCW category. When comparing the value of IC barrow carcasses within the average HCW category and above, there was a loss in primal value of carcasses from heavy IC barrows. This resulted from the extra cost to the packer for purchasing heavier carcasses. Using the 5-yr average primal price, IC barrow carcasses in the heavy HCW category were projected to return a loss of \$9.46/carcass compared to carcasses in the average HCW category. The economic analysis of data generated in this review revealed that IC barrow carcasses weighing between 90.9 to 97.7 kg had greater primal value to packers than carcasses weighing below or above that range.

Table 14. Average fixed effects of quality attributes of loins from immunologically castrated barrows categorized by hot carcass weight¹

| Item | Hot carcass weight, kg | | | SED ² | P-value |
|---------------------------------|------------------------|-------------------------|--------------------|------------------|----------|
| | Light (< 90.9 kg) | Average (90.9– 97.7 kg) | Heavy (> 97.7 kg) | | |
| pH | 5.51 ^a | 5.53 ^a | 5.66 ^b | 0.03 | < 0.001 |
| Instrumental color ³ | | | | | |
| L* | 49.36 | 48.91 | 47.38 | 0.94 | 0.06 |
| a* | 5.62 | 5.53 | 6.28 | 0.44 | 0.22 |
| b* | 3.59 | 3.46 | 3.63 | 0.47 | 0.88 |
| Subjective quality ⁴ | | | | | |
| Color | 2.44 ^a | 2.45 ^a | 3.26 ^b | 0.17 | < 0.0001 |
| Marbling | 2.09 ^a | 2.07 ^a | 1.48 ^b | 0.15 | < 0.001 |
| Firmness | 2.45 | 2.61 | 2.54 | 0.12 | 0.11 |
| Loin composition | | | | | |
| Moisture, % | 74.76 ^b | 75.16 ^b | 74.18 ^a | 0.26 | 0.01 |
| Fat, % | 1.86 ^{ab} | 1.62 ^a | 2.19 ^b | 0.18 | 0.03 |
| Drip loss, % | 2.91 | 2.92 | 2.54 | 0.23 | 0.19 |
| Cook loss, % | 22.14 | 21.32 | 22.92 | 2.07 | 0.24 |
| WB Shear force, kg ⁵ | 3.01 | 2.86 | 2.88 | 0.44 | 0.14 |

¹Sources include Pauly et al. (2009), Boler et al. (2011a, 2012, and 2014), Lowe et al. (2014, 2016b), Tavárez et al. (2014, 2016), Harris (2014), and Elsbernd et al. (2016).

²Greatest reported.

³Minolta Colorimeter, D65 illuminant. L*, greater value indicates a lighter color; a*, greater value indicates a redder color; b*, greater value indicates a more yellow color.

⁴Evaluated according to National Pork Producers Council standards for color and marbling (NPPC, 1999) and firmness (NPPC, 1991).

⁵Warner-Bratzler shear force was conducted on chops aged 14 to 21 d postmortem.

^{a,b}Means within row lacking common superscripts differ ($P < 0.05$).

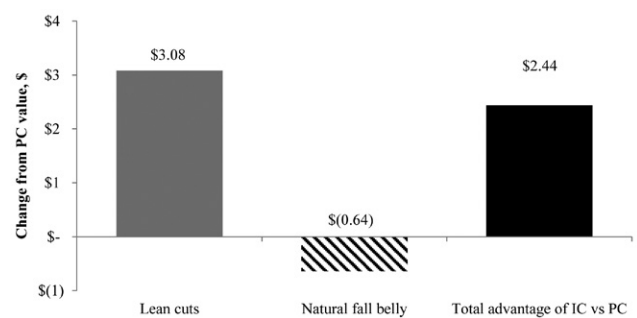


Figure 2. Effect of Improvest on value of carcasses from immunologically castrated (IC) barrows compared with physically castrated barrows (PC). Lean cuts include Boston butt, picnic shoulder, trimmed loin, spareribs, and whole ham.

Conclusion

Improvest increased carcass cutting yield by 1.24% units and lean cutting yield by 1.39% units compared with PC barrows. However, this cutability advantage decreased as IC barrows were slaughtered

Table 15. Effects of Improvest [immunologically castrated barrows (IC)– physically castrated barrows (PC)] on added primal value

| Primal | Three price scenarios: | | | | | | | | |
|--------------------------------|-------------------------------|-------|--------|---------------------|-------|--------|----------------------|-------|--------|
| | 5 yr avg. value, 2011 to 2015 | | | Best yr value, 2014 | | | Worst yr value, 2015 | | |
| | IC | PC | Effect | IC | PC | Effect | IC | PC | Effect |
| Chilled carcass wt, kg | 92.44 | 92.44 | – | 92.44 | 92.44 | – | 92.44 | 92.44 | – |
| Bone in Boston, \$ | 18.47 | 17.60 | 0.87 | 23.58 | 22.46 | 1.13 | 15.86 | 15.11 | 0.75 |
| Picnic shoulder, \$ | 15.21 | 14.67 | 0.54 | 20.07 | 19.36 | 0.71 | 11.21 | 10.82 | 0.40 |
| Whole ham, \$ | 39.07 | 38.69 | 0.38 | 51.88 | 51.38 | 0.50 | 30.27 | 29.98 | 0.29 |
| Trimmed loin, \$ | 47.11 | 46.30 | 0.81 | 54.54 | 53.60 | 0.93 | 40.10 | 39.41 | 0.69 |
| Natural fall belly, \$ | 42.40 | 43.04 | -0.64 | 44.53 | 45.20 | -0.67 | 37.54 | 38.10 | -0.57 |
| Spareribs, \$ | 11.32 | 10.83 | 0.49 | 12.21 | 11.68 | 0.53 | 12.11 | 11.58 | 0.53 |
| Total added value from primals | | | \$2.44 | | | \$3.13 | | | \$2.08 |

at heavier weights. On average, packers can expect an increase of \$2.44 in total value from IC barrow carcasses compared with PC barrow carcasses. Over a 5-yr period encompassing a worst and best year primal pricing scenario, the value of an IC barrow carcass was still between \$2.08 and \$3.13 greater than a PC barrow carcass.

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