EFFECTS OF GONADOTROPIN RELEASING FACTOR IMMUNOLOGICAL (IMPROVEST®) ON CARCASS CHARACTERISTICS, PORK QUALITY, AND FURTHER PROCESSING CHARACTERISTICS OF FINISHING MALE PIGS

BY

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DISSERTATION

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ABSTRACT

The objective of the research was to evaluate a new technology used to suppress testicular function of male pigs using an immunological designed to block the communication of gonadotropin releasing factor (GnRF) with the anterior pituitary gland. This disrupts the production of a number of male sex hormones such as testosterone and androstenone. The reduction of testosterone allows for an increase in hepatic metabolism of skatole. Androstenone and skatole are the two primary compounds associated with objectionable odors and aromas collectively known as "boar taint". Boar taint issues are the one of the key reasons physical castration (surgical castration) has been so widely adopted in United State swine production systems. Improvest® (Pfizer Animal Health, Kalamazoo, MI) is a 9 amino-acid base pair GnRF conjugate that prevents boar taint in entire male pigs even when allowed to grow to ending live weights over 130 kg. This research used two populations of pigs of PIC genetics (Pig Improvement Company, Hendersonville, TN) divided over three independent experiments. The objectives of the first experiment were to determine if increasing lysine levels in the diets of immunologically castrated (IC) male pigs will increase percent fat free lean and carcass cutability. The objective of the second experiment was to determine if increasing lysine levels in the diets of IC male pigs will affect further processed product characteristics when compared to physical castrates or entire males. Raw materials for this experiment were derived from the same pigs used in the previous experiment evaluating carcass characteristics and cutability. The objectives of the final experiment were to determine if advantages in cutting yields of immunocastrated (IC) males over physical castrates, demonstrated in the first experiment, would persist when pigs were harvested at either 4 weeks (early harvest group) or 6 weeks (late harvest group) post second injection and to evaluate belly quality and bacon processing characteristics of

IC males fed a moderate level of dietary unsaturated fatty acids (DDGS). In the first experiment, 96 pigs (16 per treatment) were selected based on ending live weight (weight 48 h prior to harvest) for further analysis. The experiment used four dietary programs differing in percent lysine inclusion where the diets ranged in a low lysine level (0.7% in the late finishing diet) to a high lysine level (1.0% in the late finishing diet). Percent fat-free lean increased 3.7 percentage units in IC males as lysine level was increased from low (56.1% fat-free lean) to high (59.8% fat-free lean) dietary lysine. There were no differences ($P > 0.05$) among IC males fed low, low/medium, or medium/high lysine levels, but there was a linear increase ($P = 0.01$) in fat-free lean as dietary lysine level increased. There were no differences in shear force, cook loss, or ultimate pH ($P \geq 0.05$) among any of the treatment groups. Extractable lipid of loin chops decreased 1.01 percentage units from IC males fed the low lysine diet (2.29%) to the IC males fed the high lysine diet (1.28%). Lean cutting yields and carcass cutting yields were higher in IC males than in physical castrates, but were lower than entire males. There was a linear increase in lean cutting yield ($P = 0.05$) and carcass cutting yield ($P = 0.01$) in IC males as dietary lysine level increased. Entire males (2.85 cm) had the thinnest ($P < 0.05$) bellies of all treatment groups. There were no differences in belly thickness among IC males with the exception of the low/medium treatment group which was thicker ($P < 0.05$) than the other IC male treatment groups. In general, IC males had thinner bellies than physical castrates, but thicker bellies than entire males. Regardless of lysine level, IC males (except low/medium) had narrower flop distances than physical castrates, but wider flop distances than entire males. Cooked yield of cured bellies were not different ($P > 0.05$) among physical castrates or IC males regardless of lysine level. There were no differences ($P \geq 0.05$) in protein content or protein fat-free values in cured and smoked hams among any treatment group. A total of 156 pigs (78 IC males and 78

physical castrates) were used in the second population of pigs. Selection criteria were based on sex and ending live weight where the heaviest 15 pigs within a pen were selected at 4 weeks post-second injection and the remaining 10 pigs in the pen were selected at 6 weeks post second injection. Pigs were harvested at either 4 or 6 weeks post-second injection and within each harvest group pigs were classified as heavy, light, or median weight. There were no differences between IC males and physical castrates for shear force (P = 0.09), ultimate pH (P = 0.57), L* (P = 0.93), a* (P = 0.33), b* (P = 0.31), subjective color score (P = 0.64), or drip loss (P = 0.30). There were no interactions between sex and harvest time (P = 0.99) or between sex and weight category (P = 0.43) or the three-way interaction (P = 0.84) for lean cutting yields. There were also no interactions between sex and harvest time (P = 0.49) or between sex and weight category (P = 0.66) or the three-way interaction (P = 0.28) for carcass cutting yields. Lean cutting yields of IC males (28.84 kg) were 1.20 kg heavier, 2.62 percentage units higher (P < 0.0001), than physical castrates (27.64 kg) and carcass cutting yields were 1.06 kg heavier, 2.27 percentage units higher (P < 0001), for IC males (33.98 kg) when compared to physical castrates (32.91 kg). Bellies from IC males were thinner (P = 0.01) and had wider belly flops (P < 0.0001) than bellies from IC males. Even though cook loss percentage was greater (P < 0.0001) in IC males when compared to physical castrates, cooked yields were not different (P = 0.74) between the two sexes. Over both populations of pigs, immunological castration with Improvest® does not affect pork quality, improves cutting yields, makes fresh bellies thinner, but does not affect cured product characteristics.

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CHAPTER I

REVIEW OF THE LITERATURE

INTRODUCTION

Gonadotropin releasing factor (GnRF) immunological (Improvac®, Improvest, Vivax®, Innosure®), used to immunologically castrate male pigs, has increased in popularity in recent years to take advantage of an entire male pig's ability to grow leaner and more efficiently than physically castrated males (Campbell et al., 1989; Andersson et al., 1997; Dunshea et al., 2001). The immunological was developed in Australia and has been available for commercial use in Australia and New Zealand since 1998 (Improvac, 2010). The immunological has since been approved in over 50 countries and is currently awaiting approval in the United States. Approval of the product is also pending in Canada. Immunological castration was described in a review by Dunshea et al. (2005) as a way to allow pigs to be produced in a manner where entire male pigs can benefit from their own testicular steroids to provide a lean growth advantage over castrated males and then be immunized at the appropriate time to eliminate any detrimental effects those steroids may cause such as objectionable odors or off flavors.

GONADOTROPIN RELEASING FACTOR

Gonadotropin releasing factor is a neuropeptide that is released in a pulsatile manner. It is a sex hormone in both males and females that is synthesized from a precursor molecule called *GnRH-associated peptide* (GAP), and secreted in the medial preoptic nucleus of the hypothalamus in the brain (Davidson and Stabendeldt, 1997). Axons in the brain transport GnRF from the hypothalamus to the median eminence where it is released into the venous portal system (Davidson and Stabendeldt, 1997). Gonadotropin releasing factor is released into the

system where it can be up- or down-regulated based on physiological requirements. In females, the system is increased during the follicular phase (follicle development) and decreased during the luteal phase (ovulation) of the estrous cycle. In males, the entire reproductive system is driven by GnRF synthesis in the hypothalamus and targets gonadotropic cells in the anterior pituitary. Once GnRF has reached and stimulated the anterior pituitary, two more sex hormones are synthesized, follicle stimulating hormone (FSH) and luteinizing hormone (LH). Like females, GnRF is released in a pulsating manner. Irregular, low- amplitude GnRF results in FSH release and high frequency GnRF pulses lead to LH release (Davidson and Stabendeldt, 1997).

These two hormones, LH and FSH, regulate the synthesis of testosterone. This is achieved by LH traveling from the anterior pituitary to the testes. Once in the testes, LH binds to membrane receptors on the leydig cells of the testes and causes a conversion of cholesterol to testosterone (Davidson and Stabendeldt, 1997). Testosterone and FSH target receptors in sertoli cells of the seminiferous tubules which activates synthesis of androgen-binding protein. It is believed sertoli cells and leydig cells communicate via paracrine signaling completing a positive feedback loop of the two hormones. Immunologically blocking the signal from GnRF decreases the production of LH, FSH, and testicular steroids (Zamaratskaia et al., 2008). Decreased levels of testosterone allow increased hepatic metabolism of negative compounds associated with meat derived from entire male pigs.

BOAR TAINT

Boar taint is loosely defined as offensive odors and off-flavors present in the meat of intact sexually mature male pigs (Zamaratskaia et al., 2008). Boar taint is considered a sensory issue that will lead to dissatisfaction with the experience of eating pork. It is generally considered an issue with intact males but is not gender exclusive. Boar taint can be detected in

barrows and gilts, particularly in cases where pigs are housed in conditions of poor environmental hygiene. Historically, sexually mature entire males have not been used in finishing production systems because of their tendency to cause objectionable odors and undesirable flavors in the meat (Babol and Squires, 1995). Boar taint is caused primarily by the accumulation of two lipophilic substances in the fat tissue of intact male pigs and some physically castrated males and gilts. The compounds that are primarily responsible for boar taint are androstenone (5α-androst-16-en-3-one) (Patterson, 1968; Zamaratskaia et al., 2008) and skatole (3-methyl-indole) (Zamaratskaia et al., 2008; Fuchs et al., 2009). Androstenone is a testicular steroid produced by the Leydig cells of the testes, and skatole is a by-product from the microbial digestion of tryptophan in the hind gut. Therefore, skatole can also be influenced by diet (Andersson et al., 1997; Zamaratskaia et al., 2005) or environment (Zamaratskaia et al., 2008) and causes issues with boar taint in barrows, gilts, and boars. Testosterone and androstenone inhibit hepatic metabolism of skatole which allow it to accumulate in fat tissue of both male and female pigs (Babol et al., 1999).

Boar taint is difficult to quantify because its perception as favorable or unfavorable is quite varied among consumer panelists. Androstenone is often described as a urine-like odor while skatole is often described as having more of a fecal odor. Detectable limits of androstenone and skatole are also quite varied among consumers. Desmoulin et al. (1982) established an accepted historical detectable limit for androstenone of 1.0 μg/g fat for untrained consumers. Detectable skatole limits have been established between 0.2 μg/g and 0.25 μg/g fat for untrained consumers (Bonneau, 1998).

Boar taint is most commonly controlled in the United States and other countries by physical castration at a very young age. The thought is to remove the problem before it becomes

a problem. Other countries who do not castrate male pigs often slaughter younger (prior to sexual maturity) at a lighter finished weight than the United States. Immunological castration has proved to be just as effective as physical castration to eliminate boar taint by reducing androstenone and skatole levels (Dunshea et al., 2001; Zamaratskaia et al., 2008; Font i Furnols et al., 2009).

GROWTH CHARACTERISTICS OF IMMUNOCASTRATED MALE PIGS

Raising boars for pork production has significant economic advantages over castrates. Boars are more feed efficient, and tend to produce leaner carcasses than barrows or gilts (Babol and Squires, 1995; Bonneau, 1998; Dunshea et al., 2001). McKeith et al. (2009) summarized the current literature and noted immunologically castrated males have improved average daily gains (ADG), and approximately 7% improvement in efficiency when compared to physical castrates. Improvements in growth and efficiency of immunologically castrated males have been well documented in several peer reviewed articles when compared to physical castrates.

Dunshea et al. (2001) reported immunologically castrated male pigs had a 10% improvement in ADG over entire males and a 7% improvement in ADG of physical castrates during the last 4 weeks of feeding prior to harvest (time post-second injection) in pigs harvested at 23 weeks of age. Furthermore, ADG of immunocastrates was improved 30% compared to entire males and improved 32% compared physical castrates during the last 4 weeks of feeding prior to harvest in pigs harvested at 26 weeks of age. Dunshea et al. (2001) cautions the improvement in efficiency of immunocastrated males over entire males reported in other studies is likely due to increased feed intake, after the second injection, rather than an improvement in conversion. Feed intake for immunocastrated males in that study was 15% higher ($P = 0.006$)

than entire males from the time of second injection until harvest, but feed conversion ratios (g/g) were similar (3.03 for entire males vs. 3.05 for immunocastrated males).

Contrary to Dunshea et al. (2001), Zamaratskaia et al. (2008) reported no differences in ADG of entire male pigs, immunocastrated male pigs, or physically castrated male pigs during the growing phase through the time of the second injection. However, after the 2nd injection immunocastrated males grew 150 g/d more than entire males (1257 g/d for immunocastrated vs. 1107 g/d for entire males) and 170 g/d more than physical castrates (1257 g/d for immunocastrated vs. 1090 g/d for physical castrates). Feed conversion ratios were also similar for immunocastrated males (3.05 kg/kg), physically castrated males (3.20 kg/kg) and entire males (2.90 kg/kg) ($P = 0.14$). Feed intake in this study was not different ($P = 0.13$) among the 3 treatment groups (Immunocastrated = 294 kg, Physical castrate = 318 kg, Entire male = 280 kg).

Jaros et al. (2005) also did not report a difference ($P = 0.35$) in ADG during the grow/finish stage of production between physical castrates (0.82 kg/d) and immunocastrates (0.83 kg/d). Average daily gain and feed intake values were not reported in this study to determine differences in growth rates after the second injection.

CARCASS CHARACTERISTICS OF IMMUNOCASTRATED MALE PIGS

It has been well defined that percent lean meat is increased in immunocastrated males when compared to physical castrated males (Dunshea et al., 2001; Jaros et al., 2005; Zamaratskaia et al., 2008; Fuchs et al., 2009). This is likely due to immunocastrated males resembling entire males for a large portion of their growth curve. In a study by Andersson et al. (1997), entire males (64.2% lean meat) expressed a 4 percentage unit advantage in lean meat content by means of partial dissection estimates when compared to physical castrates (60.1%). This increase in lean meat content of immunocastrated males compared to physical castrate

males is usually coupled with a reduction in back fat. The advantages in estimates of lean meat percentages have been described in at least four peer reviewed publications and in a summary of several Pfizer Animal Health (Kalamazoo, MI) sponsored reports.

In a review of 16 world-wide studies, McKeith et al. (2009) reported an average 3.8 percentage unit increase in percent lean estimates of immunocastrated male pigs when compared to physically castrated male pigs. In the review immunocastrated males had higher estimates of percent lean in 14 of the 16 studies and of those 8 of them were statistically ($P < 0.05$) higher.

Fuchs et al. (2009) used 554 terminal crossbred male pigs separated into physically castrated males (n = 274) and immunocastrated males (n = 280). Pigs were housed in 2 barns in pens of 26 pigs per pen. Pigs were slaughtered over 2 harvest days. Initial harvest selection (n = 242) was at 24 weeks of age and included all pigs weighing at least110 kg. It is interesting to point out there was a statistical difference (P = 0.06) in ending live weight between the physical castrates (110.2 kg) and immunocastrates (107.6 kg) with the immunocastrates not meeting the authors slaughter criteria for harvest selection on the first harvest date. The remaining pigs (n = 241) were harvested at 26 weeks of age. Percent lean meat was estimated using a Hennesy Probe. Estimated lean meat percentage was 1 percentage unit higher (P < 0.0001) in immunocastrated males (54.8%) when compared to physically castrates males (53.8%) (Fuchs et al., 2009). Carcasses were categorized based on percent lean meat estimation using EUROP standards: > 55% lean meat graded E, 50% - 54.9% graded U, 45% - 49.9% graded R. Ninety-six percent of all immunocastrated males graded at least 50% lean meat (Grade E or U) and 49% graded E, compared to 91% of the physically castrated males grading E or U with 36% grading E.

In 2008, Zamaratskaia et al. (2008) reported a 1.2 percentage unit advantage in lean meat content of immunocastrated pigs (56.1%) over physical castrated pigs (54.9%) when percent lean was estimated with a Hennessy probe. These estimates were however, not statistically different ($P > 0.05$). As expected both physical castrates and immunocastrates had lower ($P < 0.05$) estimated percent lean values when compared with entire males (57.8%). The authors followed up on the Hennessy probe estimates for percent lean by conducting a partial carcass dissection to get another parameter estimate for percent lean. The ham from the right side of each carcass was initially weighed and skinned, trimmed to a standardized fat level, and reweighed to calculate a lean meat percentage estimate. With this set of values estimate percent lean was statistically different ($P < 0.05$) between the immunocastrated males (58.5%) and the physically castrated males (56.5%). Both groups still had lower ($P < 0.05$) percent lean estimates than entire males (60.2%) (Zamaratskaia et al., 2008).

Jaros et al. (2005) also reported higher ($P < 0.001$) estimates for percent lean of immunocastrated male pigs when compared to physical castrates. The study used 533 (270 immunocastrates and 263 physical castrates) pigs that were slaughtered at an ending live weight between 100 kg and 110 kg. At harvest, pigs were ultrasounded to determine estimates of percent lean. Estimated percent lean was expressed as lean meat as a percent of carcass weight. Immunocastrated males were estimated with a 95% confidence interval, to have estimated percent lean values between 54.3% and 54.7%. Confidence intervals for physical castrates were between 53.5% and 54.0%. Average estimated percent lean was 54.5% for immunocastrates and 53.8% for physical castrates (Jaros et al., 2005).

Even though estimated percent lean was not reported by Dunshea et al. (2005), immunocastrated male pigs had less back fat at the P2 location than physical castrates. In that

study, three genders of pigs (physical castrates, immunocastrates, and immunocastrate with placebo) were divided into two groups. Pigs were harvested based on their group designation at 23 or 26 weeks of age. In each group the immunocastrated and immunocastrated placebo groups were vaccinated at 4 and 8 weeks prior to slaughter. In the group of pigs slaughtered at 23 weeks of age the immunocastrate group (11.9 mm) was 2.5 mm leaner at the P2 location near the last rib than the physical castrates (14.4 mm). In the group of pigs slaughtered at 26 weeks of age the immunocastrate group (15.1 mm) was 2.0 mm leaner than the physical castrates (17.1) (Dunshea et al., 2005). In that study, as with others, immunocastrates are not as lean as entire males. Similarly, Oliver et al. (2003) reported 2.5 mm less P2 fat on entire males when compared to immunocastrated males. The findings of that experiment agree with McKeith et al. (2009) where, 22 of 28 studies reviewed, fat thickness was reduced by 10.2 percentage units in immunocastrated males compared to physically castrated males.

The advantages in carcass leanness are not the only differences in carcass characteristics between immunocastrated males and physically castrated males. Dressing percentage of immunocastrated male pigs is often reduced by approximately 2% when compared to physically castrated males. This is likely due presence of testicles (~ 1 kg), and associated tissues such as bulbo-uretheral gland, seminal vesicles, and thicker skin present in entire and immunocastrated males. Dunshea et al. (2001) noted testicle size was reduced by over 5% from the time the second dose was given until slaughter. And testicle weight was significantly reduced ($P < 0.001$) in immunocastrated males when compared to placebo treated males in both the 23 week old and 26 week old harvest groups (Dunshea et al., 2001). This study does not agree with Oliver et al. (2003) however, who reported nearly a 2 percentage unit decrease in dressing percentage of immunocastrated males (75.7%) when compared to entire males (77.6%) Even with the

expected reduction of testicle weight of immunocastrated males, the presence of testicles that must be removed during slaughter still results in a disadvantage in dressing percentage when compared to physical castrates.

PORK QUALITY OF IMMUNOCASTRATED MALE PIGS

Immunocastration does not have any negative effects on pork quality. Several peer reviewed manuscripts and multiple internal Pfizer Animal Health (Kalamazoo, MI) reports have indicated no detrimental effects to ultimate pH, loin color, water holding capacity, or tenderness between physical castrates and immunocastrated males. In a report by McKeith et al. (2009) of 16 international studies and 1 domestic study only, one reported a statistical difference of ultimate loin pH , two instances in Minolta L* values, no instances in United States subjective NPPC color scores, no instances in drip loss, and only 1 instance of a difference in tenderness. In the single case of a difference in ultimate pH, the magnitude of the difference was 0.20 pH units. In all of the other studies the magnitude of the difference was no greater than 0.18 pH units. Minolta L* values were darker (lower L* value) in immunocastrated males compared to physically castrated males in cases. Immunocastrated male pigs were less tender than castrates in only one case.

Zamaratskaia et al. (2008) reported no statistical differences ($P = 0.76$) in ultimate loin pH between physically castrated males (5.45) and immunocastrated males (5.44) as well as no difference ($P = 0.42$) in ultimate pH of the biceps femoris in physically castrated males (5.49) and immunocastrated males (5.52).

CARCASS CUTTING YIELDS OF IMMUNOCASTRATED MALE PIGS

To date only two peer reviewed articles have been published on carcass cutting yields of immunocastrated male pigs. Fuchs et al. (2009) determined cutting yields of the boneless ham,

shoulder, loin, and belly using an AutoFOM ultrasound system. No differences ($P > 0.05$) were detected in weights of the boneless ham, loin, or shoulder between immunocastrates and physical castrates. Immunocastrate bellies were 0.5 kg lighter ($P = 0.0042$) than bellies of physical castrates (Fuchs et al., 2009). This is likely due to the bellies of the immunocastrate group being leaner and thinner than the bellies of the physical castrates. Belly percent lean estimates of physical castrates (50.5%) were 2.1 percentage units lower ($P < 0.0001$) than belly percent lean estimates of immunocastrates (52.6%).

Rikard-Bell et al. (2009) evaluated primal cut proximate composition of immunocastrated pigs. In that study, the composition of the shoulder, loin, belly, and ham were determined on entire males and immunocastrated males fed either 0 ppm, 5 ppm, or a 5 ppm to 10 ppm step-up regimen of Ractopamine hydrochloride (RAC). Shoulders of IC males had less kg of lean ($P = 0.012$) and more kg of fat ($P = 0.01$) than entire males, but had more kg of lean and less kg of fat than gilts. The same lean to fat advantage was consistent for the other four primal pieces. In each of the other pieces Entire males had more lean and less fat than immunocastrated males who had more lean and less fat than gilts.

SENSORY CHARACTERISTICS OF IMMUNOCASTRATED MALE PIGS

Sensory characteristics of immunocastrated male pigs are probably one of the most studied and best characterized topics. A number of countries such as Great Britain, Spain and Australia harvest entire males (Babol and Squires, 1995), but usually at a much lighter ending live weight than United States swine producers. Other countries such as the United States, Canada, and Brazil harvest physically castrated males. Both of these approaches (light slaughter weight and physical castration) are a means to control the negative odors and off flavors associated with consumption of boar meat. Babol and Squires (1995) reported boar taint only

occurs in a very small portion of the population of entire males harvested for food and only a small portion of consumers are sensitive to boar taint. However, Desmoulin et al. (1982) reported an 18% occurrence of boar taint (androstenone levels > 1.0 µg/g) and another 36% of the having androstenone levels between 0.50 µg/g and 1.0 µg/g in entire males. Therefore, it is a major goal of pork packers to eliminate nearly all opportunities for an incidence of boar odor to occur.

To date, peer reviewed literature indicates immunocastration with a GnRF vaccine is very effective at preventing the development of boar taint. Dunshea et al (2001) reported an 8 fold reduction ($P < 0.001$) in fat androstenone levels in placebo treated boars compared to immunocastrated males. The authors also reported no differences ($P > 0.10$) from physical castrates even though they had androstenone levels 51% lower than immunocastrates. Boar taint parameters were further evaluated by determining percent of pigs over historical thresholds for boar taint levels. In this manner, 49% of placebo treated boars had androstenone levels above 1.0 µg/g while only 3% of the immunocastrated males had androstenone levels between 0.5 µg/g and 1.0 µg/g. Skatole reductions were similar to androstenone levels. Only 1% of immunocastrated boars had skatole levels above the threshold of 0.20 µg/g while 11% of the placebo treated boars had fat skatole levels above the 0.20 µg/g threshold. Every physically castrated male in the study was below the threshold for both skatole and androstenone. If the 1% incidence of immunocastrated male pigs having skatole levels greater than 0.20 µg/g is extrapolated to include all the males harvested in the United States nearly 500,000 could have some detectable level of boar taint.

Comparing sensory characteristics between gilts, physical castrates, immunocastrates and entire males has recently been reported using consumer panels (Font i Furnols et al., 2008) and

trained sensory evaluators (Font i Furnols et al., 2009). Eighty total pigs, 20 of each gender, including gilts, physical castrates, immunocastrates, and entire males, just less than 6 months old were slaughtered and used for consumer taste panel analysis of odor and flavor (Font i Furnols et al., 2008). In that study, 10 consumers per panel evaluated 4 samples, 1 from each gender, using a 9 point hedonic scale where 1 was "dislike a lot" and 9 was "like a lot". There were no differences among immunocastrates and physical castrates or gilts in the frequencies of consumer scores for either odor or flavor. The frequency of "dislike" and "dislike a lot" for odor of entire males were higher than the frequency of "dislike" and "dislike a lot" for immunocastrated males. The frequency of "like" scores for odor was lower for meat from entire males than from immunocastrated males. Similarly, "dislike a lot" frequencies were higher in entire males than immunocastrates for flavor. Also, "like a lot" frequencies were lower in entire males than immunocastrated males (Font i Furnols et al., 2008). Entire males received a "dislike a lot" or "dislike" score for odor by 41% of the consumers on the panel where only 20.1% of immunocastrated pigs received a dissatisfactory score. Flavor score frequencies had similar results. Entire males received a dissatisfaction flavor score by 33% of panelists while immunocastrated males received a dissatisfaction flavor score by 14.5% of panelists (Font i Furnols et al., 2008).

Sensory characteristics were also similar between physical castrates and immunocastrates when evaluated by an untrained consumer panel. Another study used 95 pigs (females, entire males, physically castrated males, or immunocastrated males) to evaluate the effect of immunocastration on the sensory characteristics (odor and flavor) of the longissimus lumborum of pigs harvested at approximately 24 weeks of age (Font i Furnols et al., 2009). Odor analysis

was done by cutting cubes of meat with 3 mm subcutaneous fat and heating them in a glass tube to 180 °C for 10 min.

After a round table discussion using samples with known levels of androstenone and skatole, panelists were asked to describe odors using the following descriptors: androstenone, skatole, sweetness, and toast. Flavor profile was described with the following descriptors: androstenone, skatole, sweetness, and metallic. Texture was described with hardness and juiciness. Androstenone and skatole levels were also tested to validate consumer conclusions. Consumers reported entire males had higher ($P < 0.05$) androstenone and skatole odor levels than immunocastrates, physical castrates, or gilts (Font i Furnols et al., 2009). Entire male sweetness odors were lower ($P < 0.05$) than all other sexes. Toast odors for immunocastrates were not different from any other sexes. Androstenone and skatole flavor scores were higher ($P < 0.05$) for entire males than any other sexes. Sweetness flavor scores were lower ($P < 0.05$) for entire males than any other sexes (Font i Furnols et al., 2009). Metallic scores for immunocastrates were lower ($P < 0.05$) than females, but similar ($P > 0.05$) to physical castrates and entire males. Juiciness scores for immunocastrate males were similar ($P > 0.05$) to physical castrates and females. All 3 sexes were juicier ($P < 0.05$) than entire males (Font i Furnols et al., 2009).

IMMUNOLOGICAL CASTRATION AND RACTOPAMINE HYDROCHLORIDE

Ractopamine hydrochloride was approved in the United States for use in finishing swine diets in 1999. Since then it has been extensively studied to determine its effects on growth, tissue deposition, carcass cutting yields, pork quality, and animal behavior. Its popularity has persisted because it increases hot carcass weight (Rincker et al., 2009), increases loin eye area (Carr et al., 2009), and increases carcass cutting yields (Carr et al., 2005). The other advantage to feeding RAC is versatility. The improvements in carcass traits when feeding RAC are

consistent when feeding pigs in a short-on-space (fed to a certain number of days) (Armstrong et al., 2004) or a long-on-space (fed to a common ending live weight) (Patience et al., 2009) production strategy. Furthermore, RAC can be legally included in finishing swine diets at 5 to 10 ppm.

To date only two peer-reviewed articles and 1 internal Pfizer article have reported the interactive effects between RAC and immunocastration. Rikard-Bell et al. (2009) used 286 pigs consisting of immunocastrates, entire males (190 total males), or gilts (n = 96) to test a step-up RAC program. Pigs were allocated at 17 weeks of age by breed (terminal sire line, Myora large white, or Myora Landrace) and sex. The experiment fed RAC to pigs for 31 days prior to harvest where RAC was fed at 5 ppm for 14 days and then increased to 10 ppm for the last 17 days of feeding. An initial dose the immunological was given to 96 randomly selected entire males at 11 weeks of age. At 17 weeks of age pigs were assigned to pens based on body weight and back fat thickness within a sex and breed, and second injections were given to the immunocastrated group. The study concluded the effects of RAC and immunocastration appear to be additive in improving growth performance and carcass composition (Rikard-Bell et al., 2009). The study reported no interactions ($P > 0.05$) for any growth parameters between RAC and immunocastration, except for feed intake, over the entire 31 day feeding period of RAC. There were no interactions between RAC and immunocastration for carcass characteristics.

Ractopamine hydrochloride reduced ($P < 0.05$) feed intake of immunocastrated males from 3.04 kg/d for controls to 2.82 for the RAC fed group at day 0 to 14 post second injection when RAC was fed at 5 ppm. Feed intake of RAC-fed immunocastrates was numerically lower ($P > 0.05$) at both day 15 - 31 of feeding (10 ppm) and during the entire RAC feeding duration (day 0 to 31 post second injection). When RAC was included in the diets as a step up program

from 5 ppm to 10 ppm over a 31 day feeding period, immunocastrated males grew 15% more than entire males fed RAC.

Immunocastrated males fed RAC were 1.90 kg heavier (P = 0.001) than immunocastrated males not fed RAC. Immunocastrated males had more (P = 0.01) lean (26.5 kg) and less (P = 0.004) fat (4.65 kg) than immunocastrated male not fed RAC (23.3 kg lean and 7.30 kg of fat). This translated to an advantage in percent lean of 5.8% for immunocastrated males fed RAC versus immunocastrated males not fed RAC.

Another study evaluating the interactive effects of immunocastration and RAC fed 60 male pigs (30 entire males and 30 immunocastrated males) 1 of 3 RAC inclusions (0 ppm, 5 ppm for the last 26 days of feeding prior to harvest, or 5 ppm for 14 days followed by 10 ppm for 12 days) (Moore et al., 2009). That study did not show a main effect advantage of percent lean from feeding RAC to finishing pigs (P = 0.57). Even so, immunocastrated males fed 0 ppm RAC had percent lean estimates of 66.4% and immunocastrated males fed 5 ppm for 26 days had a 2.5 percentage unit advantage in lean percent lean estimates (68.9%). Lean to fat ratios were also improved (P = 0.62) in IC males when fed 5 ppm RAC (5.52) compared with immunocastrated males fed 0 ppm RAC (4.39)

DISTILLERS DRIED GRAINS WITH SOLUBLES (DDGS) IN FINISHING SWINE DIETS

Stein and Shurson (2009) reported DDGS can effectively be included in swine diets at all phases of production systems. The review evaluated 25 studies from the last 10 years for parameters of growth characteristics, carcass characteristics, and pork quality. Growth performance is not different in grower-finisher pigs when DDGS is included up to 20% of the diet when compared to grower-finisher pigs fed a standard corn-soybean meal diet (Stein and

Shurson, 2009). Four reviewed studies all agree, average daily feed intake, average daily gain, and gain to feed ratios are not compromised by including DDGS up to 20% inclusion in grow-finish diets (Stein and Shurson, 2009).

Carcass characteristics have also been evaluated comparing DDGS diets and corn-soybean meal control diets. In ten of eighteen experiments reviewed, dressing percentage was not affected; in fourteen of fifteen experiments reviewed, back fat thickness was not affected; and in twelve of fourteen studies reviewed, loin eye depth was not affected by dietary DDGS inclusion (Stein and Shurson, 2009).

One of the biggest concerns using DDGS in the meat industry is the effect of DDGS on further processed product characteristics such as belly firmness and sliceability of bacon manufactured from pigs fed high levels of DDGS. Leick et al. (2010) evaluated belly firmness, bacon slice cook loss, shelf life, and fatty acid profiles of pigs fed 0%, 15%, 30 %, 45%, and 60% DDGS in swine finisher diets. Belly flop distance linearly decreased ($P = 0.0005$) and iodine value linearly increased ($P < 0.0001$) as dietary DDGS level increased. Bellies also became thinner ($P = 0.0002$) as DDGS level was increased, but this did not affect the ability of the belly to take up brine ($P = 0.29$). Cook yield was not reported, so it cannot be determined if the bellies, regardless of treatment were able to retain the same amount of brine. Cook loss bacon slices were not different ($P = 0.09$) among DDGS inclusion levels.

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CHAPTER II

EFFECTS OF INCREASING LYSINE LEVELS ON CARCASS COMPOSITION AND CUTTING YIELDS OF IMMUNOLOGICALLY CASTRATED MALE PIGS

ABSTRACT

The objective of this experiment was to determine if increasing lysine levels in the diets of immunologically castrated (IC) male pigs will increase percent fat free lean and carcass cutting yields. The anti-gonadotropin releasing factor (anti-GnRF) immunological product (Improvest®; Pfizer Animal Health) is used worldwide to immunologically castrate entire male pigs to control boar taint and take advantage of the inherent ability of the entire male to deposit more muscle, less fat, and grow more efficiently than physically castrated males. The immunization process essentially allows the pig to grow as an entire male pig for most of its life and then removes any boar odor (boar taint) prior to harvest. Reported lean meat advantages may also provide economic benefits to the domestic meat industry. Approximately 1200 male pigs (physical castrates, IC males, and entire males) were each assigned to one of four diet programs which differed in lysine level. In each case lysine was fed in a step-down program that culminated with the following concentrations in the late finishing diet: physical castrate - low lysine (0.7%), IC - low lysine (0.7%), IC - low/medium lysine (0.8%), IC - medium/high lysine (0.9%), IC - high lysine (1.0%), and entire - high lysine (1.0%). At 25 weeks of age (five weeks post-second injection), pigs were individually weighed and the two pigs (n = 96) in each pen closest to the median pig weight were selected and harvested. The right side of each carcass was dissected into soft tissue, skin, and bone. Proximate composition was determined on the soft tissue to determine percent fat-free lean. The left side of each carcass was weighed and initially

fabricated into ham, loin, belly, and whole shoulder. Each primal piece was weighed again and further fabricated into respective subprimal cuts. Immunological castration did not change ($P > 0.05$) shear force values or ultimate pH. Marbling linearly ($P = 0.01$) decreased as dietary lysine increased among IC males. As expected IC males had a higher ($P < 0.05$) percent fat-free lean than physical castrates but were lower ($P < 0.05$) than entire males. Immunocastrated males fed diets with medium/high and high lysine levels had higher ($P < 0.05$) lean cutting yields and carcass cutting yields than physical castrates. Lean cutting yield ($P = 0.05$) and carcass cutting yields ($P = 0.01$) both linearly increased as dietary lysine increased in IC males. Overall, immunological castration improved carcass cutability, increased percent fat free lean, and had no effect on pork quality when compared to physical castrates.

INTRODUCTION

Immunization against gonadotropin releasing factor (GnRF), also known as immunological castration has increased in popularity and availability in recent years to control boar taint at harvest and to take advantage of an entire male pig's ability to deposit more muscle and less fat than physically castrated males (Campbell et al., 1989; Dunshea et al., 2001). Historically, sexually mature entire males have not been used in some global food production systems because of their tendency to cause objectionable odors in the meat (Babol and Squires, 1995). Font i Furnols et al. (2009) reported no differences ($P > 0.05$) in odor or flavor between meat from physical castrates or immunologically castrated (IC) males. This makes the likelihood for adoption of immunological castration into production systems more likely. Lean meat advantages as well as growth and efficiency improvements have also been reported. Fuchs et al. (2009) reported a lean meat percentage advantage of IC males when compared to physically castrated males.

Past studies compared IC males with physical castrates or entire males when each sex was fed the same diet with equal lysine levels. In a typical immunological castration production system, pigs physiologically function as entire males for a large portion of their lives and then transition to become more like a physical castrate after immunization. Therefore, the lysine requirement of IC males is not known.

The objective of this study was to evaluate increasing lysine inclusion levels in grower/finisher diets of IC male pigs to maximize percent fat free lean and carcass cutting yields. Secondly, the study compared IC males with entire males fed the same diet; and compared IC males with physically castrated males fed the same diet. This information will help swine nutritionists and producers determine optimal dietary lysine inclusion levels for IC male grower/finisher diets to maximize lean tissue deposition.

MATERIALS AND METHODS

No approval was obtained from the University of Illinois Institutional Animal Care and Use Committee for this experiment because only carcasses were used in the experiment. Experimental procedures during the live phase of the experiment followed the guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. Carcasses were obtained from a United States FSIS inspected harvesting facility and then transported to the University of Illinois Meat Science Laboratory.

Allotment and Diet Schedule

Pigs were selected for harvest and fabrication from a much larger experiment that involved approximately 1200 head of commercial finisher pigs (PIC 337 x PIC 1050, Pig Improvement Company, Hendersonville, TN). Initially, pigs were randomly assigned to one of

three sexes (physical castrate, immunologically castrated (IC) male, and entire male) at one week of age. Pigs designated for the physical castrate group were surgically castrated within 10 d of birth. The study used four dietary programs differing in percent lysine inclusion (Table 2.1). The diets ranged in lysine level from the requirement for physical castrates (low - 0.7% in the late finishing diet; National Research Council, 1998) to the assumed lysine requirement for entire males (high - 1.0%). Two intermediate lysine level diets were also fed to IC males and designated as low/medium (0.8%) and medium/high (0.9%) in the late finishing phase. This resulted in six treatment groups: physical castrates fed a low lysine diet, IC males fed a low lysine diet, IC males fed a low/medium lysine diet, IC males fed a medium/high lysine diet, IC males fed a high lysine diet, and entire males fed a high lysine diet. Pigs were housed in pens of approximately 25 pigs per pen of like sex. All treatment groups were fed the same nursery diet until the pigs were 6 weeks old, after which pigs were switched to their respective treatment diets, each with a step-down lysine inclusion that culminated in the concentrations previously described. Diet schedule and specific lysine inclusion levels for the entire feeding period are described further in Table 2.1. The first of two 2 mL subcutaneous injections of an anti-gonadotropin releasing factor (anti-GnRF) immunological product (Improvest®; Pfizer Animal Health, Kalamazoo, MI) was administered to the IC males at 16 weeks of age. The second injection was administered at 20 weeks of age and all pigs were harvested five weeks post-second injection at 25 weeks of age. No placebo injection was administered to the physical castrates or entire males during either injection period.

Animal Selection

After the feeding trial, 96 pigs (16 per treatment) were selected based on ending live weight (weight 48 h prior to harvest) for further analysis. Two pigs per pen closest to the median

pig weight were identified and slaughtered at a U.S. FSIS inspected abattoir. At the time of harvest, hot carcass weight (HCW) was recorded along with loin depth (10th rib) and fat depth (10th rib) using a Fat-O-Meater system (Fat-O-Meater measurements, SFK Technology Fat-O-Meater, Herley, Denmark). Loin depth and fat depth measurements were used to calculate estimated percent lean. Dressing percentage was calculated by dividing HCW by ending live weight taken 48 h before harvest. After harvest, carcasses were chilled for approximately 24 h and transported to the University of Illinois Meat Science Laboratory in a refrigerated truck.

Carcass Measurements

The right side of each chilled carcass was ribbed at the location of the 10th rib. Backfat was measured perpendicular to the skin at the 3/4 point of the LEA at the 10th rib. Loin eye area (LEA) was measured by tracing the face of *longissimus* muscle on double matted acetate paper. Loin tracings were traced in duplicate using a Super PLANIX α polar planimeter (Tamaya Technics Inc, Tokyo, Japan) and the average of the two measurements were reported as LEA for each carcass.

Fat-Free Lean Determination

The right side of each carcass was standardized by removing any remaining pelvic canal fat and mandibular lymph nodes. After standardization, a chilled side weight was taken. Sides were skinned using an air skinner to remove less than 3 mm of skin and tissue. All bones were separated from soft tissue and knife scraped to remove residual tissue. Dissected sides were divided and weighed based on category of skin, bone and soft tissue. Soft tissue was prepared for proximate composition analysis by grinding all soft tissue twice through a 4.7 mm grinder plate using commercial meat grinder (Hobart Corporation, Troy, OH) and further homogenized with a commercial bowl chopper. A 10 g sample of soft tissue was oven dried at 110° C for

approximately 24 h to determine percent moisture. The dried sample was washed multiple times in an azeotropic mixture of warm chloroform:methanol as described by Novakofski et al. (1989). Percent fat was used to calculate percent fat-free lean using the following equation: percent fat-free lean = $\left(\frac{soft\ tissue\ wt - (soft\ tissue\ wt * soft\ tissue\ \%\ fat)}{chilled\ right\ side\ wt}\right) * 100$

Warner-Bratzler Shear Force

Chops for shear force were cut 2.54 cm thick from the longisimus muscle immediately posterior to the area of the 10th rib. Chops were vacuum packaged, stored at 4° C, and aged until 14 days post mortem. At the end of the aging period, chops were frozen and held until further analysis. Twenty-four hours prior to analysis, chops were removed from the freezer and placed in a cooler at 4° C to thaw. Chops were trimmed of excess fat and cooked on a Farberware Open Hearth grill (Model 455N, Walter Kidde, Bronx, NY). Chops were cooked on one side to an internal temperature of 35° C, flipped, and cooked to a final internal temperature of 70° C. Internal temperature was monitored using copper-constantan thermocouples (Type T, Omega Engineering, Stanford, CT) connected to a digital scanning thermometer (Model 92000-00 Barnant Co., Barington, IL). Next, chops were allowed to cool to 25° C and four 1.25cm diameter cores were removed parallel to the orientation of the muscle fibers. Cores were sheared using a Texture Analyzer TA.HD Plus (Texture Technologies Corp., Scarsdale, NY/Stable Microsystems, Godalming, UK) with a blade speed of 3.3 mm/sec and a load cell capacity of 100 kg. A single shear force was determined on each of the four cores. Shear force was reported as the average of the four cores. Cook loss was determined by weighing chops used for shear force immediately before and after cooking. Reported values are percent weight lost during cooking.

Pork Quality

Pork quality measurements for ultimate pH, objective color, subjective color, marbling, and firmness scores, and drip loss were conducted by trained University of Illinois meat science laboratory personnel. Measurements were collected on boneless Canadian back loins (NAMP #414) cut at the area of the 10th rib. Ultimate pH was measured using a hand held pH star probe fitted with a glass electrode (SFK Technologies Inc., Cedar Rapids, IA; 2 point calibration- pH 4 and 7). Objective CIE L*, a*, and b* (CIE (Commission internationale de l'eclairage), 1978) values were collected with a Minolta CR-400 utilizing a D65 light source and a 0° observer and an aperture size of 8 mm. Subjective color and marbling scores (NPPC, 1999) and firmness scores (NPPC, 1991) were conducted by a single individual according to standards established by the National Pork Producers Council. Loin muscle proximate composition was determined in the same manner described for fat-free lean proximate composition. Water holding capacity was evaluated using the drip-loss method where a 1.25 cm thick chop was suspended from a fish hook in a Whirl-pak bag for approximately 24 h at 4° C. Chops were weighed prior to and immediately after suspension. Results were reported as a percent of weight loss.

Carcass Fabrication

The left side of each chilled carcass was initially fabricated into ham, loin, belly (spareribs on), whole shoulder (neck bones removed) and jowl. Each primal piece was weighed again before further fabrication into subprimal cuts. Because of the variability in live weight and HCW across treatments, carcass cut-out data were also expressed as a percentage of chilled side weight.

Ham Hams were fabricated according to Boler et al. (2010). Hams were cut to meet the specification of a NAMP #401 and designated as a whole ham. Whole hams were skinned and

trimmed of excess fat to meet the specification of NAMP #402 to determine trimmed ham weight. Trimmed hams were fabricated into five separate pieces: inside ham (NAMP #402F), outside ham (NAMP #402E), knuckle, shank portion, and light butt. The inside, outside, and knuckle were completely denuded of fat. All five pieces were individually identified and weighed. Identities of the inside, outside, and knuckle were retained to make NAMP #402G three piece hams at a later time. Identities of the shank portion and light butt were not retained.

Loin Skin on bone-in loins were skinned to meet the specifications of a NAMP #410 loin. Trimmed loins were weighed and fabricated into a NAMP #414 Canadian back, NAMP #415A tenderloin (side muscle off), and the sirloin end.

Belly The whole sparerib-in belly was fabricated into a NAMP #408 belly and NAMP #416 spareribs.

Shoulder The whole shoulder was fabricated into a modified NAMP #404 skinned shoulder, where the picnic portion was skinned also. The Boston butt was separated from the picnic to form a NAMP #406 bone-in Boston butt and a modified skinned NAMP #405 bone-in picnic shoulder. Each piece was boned out to meet the specifications of NAMP #406A boneless Boston butt and a NAMP #405A boneless picnic shoulder. The boneless picnic shoulder was further fabricated by removing the *triceps brachii* and weighing the cushion NAMP #405B.

Cutting Yields

Bone-in lean cutting yield was calculated with the following equation: lean cutting yield $= \frac{(trimmed\ ham + trimmed\ loin + Boston\ butt + picnic)}{chilled\ left\ side\ wt} * 100$ and carcass cutting yield was calculated

with the following equation: carcass cutting yield = $\frac{(lean\ cutting\ yield\ components+trimmed\ belly)}{chilled\ left\ side\ weight} * 100$.

Statistical Analyses

Data were analyzed with the Mixed procedure of SAS (SAS Institute, 2004) as a general linear mixed model. Pen served at the experimental unit and the fixed effect in the model was treatment (sex and lysine level combination). There were 16 pigs per treatment group with two pigs per pen being selected for analysis for a total of eight replicates per treatment. Random effects were block and the interaction between block and treatment. Means separation was conducted using the PDIFF option at the treatment level. Non continuous variables (subjective color, marbling, and firmness) were analyzed with the Glimmix procedure of SAS with the same fixed and random effects listed for other parameters. Orthogonal polynomial contrasts were constructed to determine linear, quadratic, and cubic effects of dietary lysine on response parameters of IC males. Statistical differences were accepted as significant at $P < 0.05$ using a two-tailed test.

RESULTS AND DISCUSSION

Population summary statistics for all 96 selected pigs are reported for carcass characteristics, pork quality, and cutting yields in Table 2.2.

Carcass Characteristics

Ending live weights of physical castrates and IC males fed the low lysine diet were lighter ($P < 0.05$) than the other IC male treatment groups. Live weights of IC males increased linearly ($P = 0.01$) up to the medium/high inclusion level and then was slightly lower for an overall quadratic ($P < 0.01$) effect (Table 2.4). Hot carcass weight for IC males fed medium/high

lysine diets were heavier ($P < 0.05$) than physical castrates, IC males fed low or high lysine diets, and entire males. IC males fed low/medium lysine diets were similar ($P > 0.05$) to all other treatment groups. Dressing percentage was lower ($P < 0.05$) for IC males and entire males when compared to physical castrates (Table 2.3). Dressing percentage was not different ($P > 0.05$) among IC males regardless of lysine level. Dressing percentage was significantly higher ($P < 0.05$) for IC males fed medium/high lysine diets when compared to entire males. Comparisons of other IC male dietary treatment groups were not different ($P > 0.05$) from dressing percentages of entire males. Zamaratskaia et al. (2008) reported a 1.8 percentage unit reduction in dressing percentage of IC males when compared to physical castrates and a 0.6 percentage unit decrease in dressing percent in entire males when compared to physical castrates. Similar to the current study, McCauley et al. (2003) reported no differences in dressing percentage between IC males and entire males. Testicle weight was likely responsible for a portion of the reduction in dressing percentage of IC males or entire males when compared to physical castrates. Dunshea et al. (2001) also reported a reduction in dressing percentage of approximately 1.5 percentage units for entire males and IC males when compared to physical castrates. Testicle weight of entire males and IC males accounted for less than 1% of ending live weight (Dunshea et al., 2001). Thus, additional factors may be affecting the reduction in dressing percentage. Dunshea et al. (2001) speculated an increase in feed intake by IC males after the second injection could account for more gut fill and contribute to a reduction in dressing percentage. In this study, ending live weight was collected 48 h prior to harvest without a fasting period and may explain some of the reduction, but that conclusion cannot be confidently stated because neither gut fill nor testicle weight were evaluated in the current study.

IC males fed the high lysine diet had a deeper loin depth ($P < 0.05$) than entire males. No other differences ($P > 0.05$) were detected among other treatment groups for loin depth. No differences were detected for fat depth among physical castrates, IC males fed low lysine, IC males fed low/medium lysine or IC males fed medium/high lysine. Entire males had less fat depth ($P < 0.05$) when compared to the other treatment groups with the only exception being IC males fed high lysine ($P > 0.05$). Fat depths of IC males decreased linearly ($P = 0.03$) as dietary lysine increased (Table 2.4). Carcass estimated lean, as predicted with a Fat-O-Meater, was higher ($P < 0.05$) in IC males fed high lysine and in entire males when compared to physical castrates and IC males fed the two lower levels of dietary lysine. IC males fed medium/high lysine did not vary significantly ($P < 0.05$) from any of the other treatment groups. Thus, based on estimation of carcass percent lean, dietary lysine level is important for IC males to attain carcass lean percentages comparable to entire males and increased linearly as dietary lysine level increased (Table 2.4).

Physical carcass measurements were also collected on each carcass. Loin eye areas of physical castrates were smaller ($P < 0.05$) than LEA of IC males fed medium/high lysine, IC males fed high lysine, and entire males. There were no differences ($P > 0.05$) in LEA among IC males regardless of lysine level (Table 2.3). Based on backfat thickness, entire males were the leanest ($P < 0.05$) among all treatment groups. There were no differences ($P > 0.05$) in backfat thickness among physical castrates and IC males regardless of dietary lysine level. Fuchs et al. (2009) also reported higher fat depths for physical castrates over entire males. Many researchers, in studies involving IC males, reported estimated lean using various technologies including the Fat-O-Meater (Gispert et al., 2010), ultrameter (Jaros et al., 2005) and the Hennessy probe (Fuchs et al., 2009; Rikard-Bell et al., 2009). The current study agrees with each of the

previously listed studies where IC males have a higher estimated lean (range 55.8% - 57.5%), using a Fat-O-Meater, than physical castrates (55.2%), but a lower estimated lean than entire males (58.0%) even though the magnitude of the differences did not reach statistical significance (Table 2.3). However, the high lysine IC males (57.5%) had a higher ($P < 0.05$) lean meat estimate than physical castrates (55.2%).

In contrast to other studies that only used the Fat-O-Meater, in this experiment, sides were cut to determine fat-free lean (Table 2.3). Right sides of the carcass were separated into skin, bone, and soft tissue. Bone weight was heavier ($P < 0.05$) in entire males than either IC males or physical castrates with the exception of the IC males fed the medium/high lysine diet where bone weights were not different ($P > 0.05$). Proximate composition was determined on the soft tissue. It appears from this population of pigs, the Fat-O-Meater detected relatively fewer differences in estimated lean percentages across treatment groups, and where differences were detected statistically ($P < 0.05$), the magnitude of the differences were smaller when compared to fat-free lean data from physical dissection and chemical analysis.

Fat-free lean was lower ($P < 0.05$) for physical castrates (53.8%) when compared to entire males (64.2%) or any of the IC male dietary treatment groups (range 56.1% - 59.8%). Entire males had the highest ($P < 0.05$) fat-free lean of any other treatment groups (Table 2.3). Percent fat-free lean increased 3.7 percentage units in IC males as lysine level was increased from low (56.1% fat-free lean) to high (59.8% fat-free lean) dietary lysine. There were no differences ($P > 0.05$) among IC males fed low, low/medium, or medium/high lysine levels, but there was a linear increase ($P = 0.01$) in fat-free lean as dietary lysine level increased (Table 2.4). Witte et al. (2000) reported an increase in carcass lean when dietary lysine levels increased from

4.8 g/kg to 6.4 g/kg. Fat-free lean percentage was higher ($P < 0.05$) in the high lysine IC males than the IC males fed low or low/medium levels, but lower ($P < 0.05$) than in the entire males.

Pork Quality

There were no differences in shear force, cook loss, or ultimate pH among any of the treatment groups (Table 2.5). The lack of significant differences in muscle pH was expected, as other researchers reported varying protein levels in finishing swine diets did not affect muscle pH (Goerl et al., 1995; Witte et al., 2000; Szabó et al., 2001). Zamaratskaia et al. (2008) also reported no differences in ultimate pH among physical castrates, IC males, or entire males in either the longissimus or the biceps femoris muscles. Gispert et al. (2010) agreed and reported no differences in longissimus ultimate pH among physical castrates, IC males, entire males, or gilts. Furthermore, Pauly et al. (2009) reported no differences in 30 min postmortem longissimus pH or ultimate pH among entire males, IC males, or physical castrates.

There were significant differences ($P < 0.05$) among treatments for objective color scores and subjective evaluations, but the magnitude of differences between treatments were relatively small and within the range of consumer acceptability. Zhu and Brewer (1999) reported at least a two-L* unit difference was required before consumers could distinguish color differences. Entire males had L* values (48.07) that were lower ($P < 0.05$) than all other treatment groups, but the L* range (53.33 - 55.86) among the other treatment groups just slightly exceeded (2.53) the two-unit requirement of Zhu and Brewer (1999). Differences in L* values between entire males and other sexes were reported previously by Gispert et al. (2010). Pauly et al. (2009), however, was unable to detect differences in objective L* between entire males and IC males or physical castrates.

Physical castrates and IC males fed the low lysine diet had higher ($P < 0.05$) loin fat percentages (% extractable lipid) when compared with the other four treatment groups. Extractable lipid decreased linearly ($P < 0.01$) as lysine level increased among IC males (Table 2.6). As expected, entire males (1.32%) had less ($P < 0.05$) extractable lipid than physical castrates (2.37%). Extractable lipid decreased 1.01 percentage units from IC males fed the low lysine diet (2.29%) to the IC males fed the high lysine diet (1.28%) (Table 2.5). The decrease in marbling in IC males as lysine level is increased could be because lysine level in the low and low/medium diets for the IC male treatment group was below their optimum growth requirement.

Drip loss was not different ($P > 0.05$) between physical castrates or entire males. Interestingly, IC males fed the medium/high lysine diet had higher ($P < 0.05$) drip loss values than IC males fed the high lysine diet. Pauly et al. (2009) reported no differences for any water-holding capacity characteristics (drip loss, thaw loss, or purge loss) among physical castrates, IC males, or entire males fed the same dietary lysine level.

Carcass Fabrication

Whole shoulder weights were heavier ($P < 0.05$) for the medium/high IC males than any other treatment groups, but when expressed as a percentage of chilled side weight there were no differences among any treatments (Table 2.7). Upon closer examination of effects of sex and dietary lysine levels on subprimal cuts, results were more variable. Bone-in Boston butt and boneless Boston butt of IC males fed high lysine and entire males had a higher ($P < 0.05$) percentage of chilled side weight than physical castrates and IC males fed low lysine. Also, bone-in and boneless Boston butt shoulders increased linearly ($P = 0.01$) as dietary lysine increased (Table 2.8). There were no differences ($P > 0.05$) in percent chilled side weight among any treatment group for bone-in picnic, boneless picnic, or cushion (*Triceps brachii*) (Table 2.7).

There were differences ($P < 0.05$) among treatment groups for the jowl, but the differences were small (range 1.84% - 2.34%) and of little practical value.

IC males fed medium/high lysine had whole loins that were significantly heavier ($P < 0.05$) than entire males. Trimmed loin weights of IC males fed medium/high lysine were not significantly different ($P > 0.05$) between IC males fed high lysine and entire males, but were heavier ($P < 0.05$) than physical castrates, IC males fed low lysine, and IC males fed low/medium lysine. When expressed as a percentage of chilled side weight, only subtle differences in whole loin and trimmed loin were detected. The Canadian back loin of IC males fed medium/high lysine, IC males fed high lysine, and entire males were heavier ($P < 0.05$) than physical castrates and IC males fed low lysine diets. But, when expressed as a percentage of chilled side weight, no meaningful differences were detected. Heavier Canadian back weights in the IC males fed high lysine and entire males compared to physical castrates are likely due to increased LEA which were also larger in IC males fed high lysine and entire males when compared to physical castrates. Statistical differences in weights of the tenderloin and sirloin were also detected, but the magnitude of the differences were small (Table 2.7). However, there was a linear increase ($P \leq 0.02$) in trimmed loin weight, Canadian back loin weight, and sirloin weight as dietary lysine increased in IC males (Table 2.8). Gispert et al. (2010) reported tenderloin muscles from physical castrates comprised a lower ($P < 0.05$) percentage of the carcass than IC males, females, or entire males. Tenderloins from entire males in this study had higher ($P < 0.05$) percentages of chilled side weight than any other treatment group. Differences in results between the two experiments may be due to inherent genetic variation in the population of the pigs used to create the two data sets. Pauly et al. (2009) reported no differences in entire

loin weights as a percentage of chilled carcass weight between physical castrates and IC males, but percentages were lower ($P < 0.05$) when compared to entire males.

There were no detectable differences ($P > 0.05$) for any treatment groups in whole ham weights as a percentage of chilled side weight (Table 2.9). There were statistical differences ($P < 0.05$) in absolute weight and as a percentage of chilled side weights in the components of the ham (inside, outside, knuckle, light butt, and shank) among treatments. In general, as dietary lysine level increased in IC male ham weights and ham component weights increased. Specifically, the knuckle ($P = 0.03$) and shank meat ($P = 0.04$) increased linearly as dietary lysine increased among IC males (Table 2.10). Belly weights were not different among IC males regardless of dietary lysine level. Belly weights were also not different between physical castrates or any of the IC male treatment groups. IC males fed medium/high lysine (5.60 kg) had heavier ($P < 0.05$) bellies than entire males (5.25 kg). This is likely due to entire male bellies being thinner ($P < 0.05$) (data not shown in tabular form) than IC male bellies.

Overall, IC males appeared to have slightly heavier primal and subprimal weights when compared to physical castrates even though the advantage did not reach statistical significance in all cases.

Cutting Yields

Cutting yields for all treatments are reported in Table 2.11. Small numerical increases in weights of the primal pieces led to significant differences in cutting yields. Entire males (66.09%) had the highest ($P < 0.05$) lean cutting yield among all other treatment groups (range 61.51% - 64.08%). The lean cutting yield advantage of the entire males was on average over 2.5 percentage units higher than any other treatment group. Physical castrates (61.51%) had lower

lean cutting yields ($P < 0.05$) than IC males fed medium/high lysine (64.08%), IC males fed high lysine (64.01%), and entire males (66.09%). IC males fed medium/high and high lysine had higher ($P < 0.05$) lean cutting yields than physical castrates by nearly 2.5 percentage units. As dietary lysine level increased in IC male diets, lean cutting yields also increased ($P = 0.05$, Table 2.10). This advantage provides major economic advantages in carcass value for IC males over physical castrates. Even though entire males had the highest lean cutting yields, problems with boar taint issues prevents entire males from being a reasonable option at this ending live weight (129.6 kg) in the U.S. and other global markets.

Carcass cutting yield results were qualitatively similar to lean cutting yield results. Entire males (77.87%) had the highest ($P < 0.05$) carcass cutting yields of any treatment group (range 73.70% - 76.33%). Physical castrates (73.70%) had lower carcass cutting yields ($P < 0.05$) than IC males fed medium/high lysine (76.12%), IC males fed high lysine (76.33%), and entire males (77.87%, Table 2.11). There was a linear increase in carcass cutting yield ($P = 0.01$) as lysine level was increased in the IC male diets (Table 2.10). The medium/high (76.12%) and high (76.33%) lysine level IC males had higher ($P < 0.05$) carcass cutting yields than IC males fed low lysine (74.28%) or physical castrates (73.70%). The differences were 1.84 percentage units between IC males fed medium/high lysine and IC males fed low lysine and 2.42 percentage units between IC males fed medium/high lysine and physical castrates. These carcass cutting yield advantages confirm lean cutting yield advantages of IC males fed a higher lysine level diet over a conventionally fed physical castrate. This was not surprising given that IC males are physiologically more like entire males for most of their lives, and entire males are known to have a higher lysine requirement. It should also be noted, the lysine program was continued

throughout the life cycle and based on physiology may warrant further investigation by reducing lysine levels after the second injection.

CONCLUSION

The use of immunological castration on intact male pigs did not have any detrimental effects on pork quality. The results of this experiment were consistent with previously reported studies in that IC males had higher percent lean values than physical castrates, but lower percent lean values than entire males. As dietary lysine level increased among the IC males backfat decreased and percent lean increased. Lean cutting yields and carcass cutting yields were higher in IC males than in physical castrates, but were lower than entire males. As dietary lysine level increased in IC males cutting yields also increased. It appears from this population of pigs, IC males should be fed a diet higher in lysine than a physical castrate to maximize cutting yields. When IC males were fed the medium/high and high lysine diet, the advantage in carcass cutting yield was about 2.5 percentage units higher than physical castrates with no negative effects on pork quality parameters (tenderness, water holding capacity, ultimate pH, or color). This advantage could have a major economic implication to U.S. and other global pork production systems.

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Table 2.1 Diet schedule and percent lysine inclusion by diet

	Diet schedule		Lysine level, % of diet			
Time Period	Age of pigs (weeks)	Approximate wt (kg)[1]	Low[2,3]	Low/Med[3]	Med/High[3]	High[3,4]
Allotment	1	2.3	N/A	N/A	N/A	N/A
Weaning	2.5	5.5	N/A	N/A	N/A	N/A
Nursery	2.5	---	Same nursery diet provided to all treatments			
Grower period	6	22.7	1.2	1.3	1.4	1.5
Developer period	11	45.4	1.0	1.1	1.2	1.3
1st Finish period (1st vaccination)	16	68.1	0.8	0.9	1.0	1.1
2nd Finish period (2nd vaccination)	20	90.8	0.7	0.8	0.9	1.0
Harvest	25	129.7				

[1]Population mean

[2]Sex = Physical castrate

[3]Sex = Immunological castrate

[4]Sex = Entire male

Table 2.2 Population summary statistics of carcass characteristics and pork quality traits

	Summary Statistics					95% CL	
Item	n	Mean	Minimum	Maximum	CV, %	Lower	Upper
Live wt, kg	96	129.7	117.6	142.1	3.8	128.7	130.7
HCW, kg	96	92.7	74.0	102.7	5.0	91.7	93.6
Dressing, %	96	71.4	59.9	75.4	3.2	71.0	71.9
Fat-O-Meater							
Loin depth, cm	96	6.7	5.4	8.2	8.9	6.6	6.8
Fat depth, cm	96	1.7	1.0	2.5	19.6	1.6	1.8
Estimated lean, %	96	56.5	51.9	62.0	3.9	56.1	57.0
Carcass measurements							
LEA, cm^2	96	47.3	35.7	66.7	11.6	46.2	48.4
Backfat, cm	96	2.2	0.9	3.3	25.0	2.1	2.3
Right side chilled wt, kg		45.1	37.6	51.0	5.0	44.7	45.6
Skin wt, kg	94	3.4	2.3	4.0	8.4	3.3	3.4
Bone wt, kg	94	6.3	4.2	7.6	8.7	6.2	6.4
Soft tissue wt, kg	96	35.0	25.6	39.8	6.6	34.5	35.5
Soft tissue moisture, %	96	62.7	53.0	71.7	6.4	61.9	63.5
Soft tissue fat, %	96	19.9	7.9	32.2	26.1	18.8	20.9
[1]Fat-free lean	96	58.0	37.7	69.1	8.7	57.0	59.1
Shear force, kg	96	2.5	1.7	4.1	18.3	2.4	2.6
Cook loss, %	96	22.5	14.6	36.8	18.7	21.6	23.3
pH	96	5.6	5.3	6.1	2.1	5.5	5.6
Objective color							
L*	96	53.5	41.3	63.6	8.2	52.6	54.4
a*	95	4.8	1.3	7.6	29.9	4.5	5.0
b*	96	7.9	4.2	11.0	21.0	7.6	8.3
[2]Subjective evaluations							
Color	96	2.8	2.0	3.0	12.8	2.8	2.9
Marbling	96	2.4	1.0	4.0	28.3	2.3	2.6
Firmness	96	3.0	2.0	4.0	9.7	2.9	3.0
Loin composition							
Moisture, %	96	75.2	73.4	77.5	1.1	75.1	75.4
Fat, %	96	1.8	0.4	4.1	44.1	1.6	1.9
Drip loss, %	96	2.5	0.4	6.7	42.4	2.3	2.7
Left side chilled wt, kg	96	44.9	34.3	49.7	5.3	44.4	45.4
[3]Lean cutting yield, %	96	63.6	58.1	71.3	3.9	63.0	64.1
[4]Carcass cutting yield, %	96	75.5	65.1	82.9	3.5	75.0	76.1

[1]Fat-free lean =((soft tissue wt - (soft tissue wt * soft tissue % fat) / right chilled side wt)*100

[2]Subjective evaluations based on standards provided by the National Pork Producers Council

[3]Lean cutting yield = ((trimmed ham + trimmed loin + Boston + picnic) / left chilled side wt)*100

[4]Carcass cutting yield = ((lean cutting yield components + trimmed belly) / left chilled side wt)*100

Table 2.3 The effect of GnRF immunological on carcass characteristics of finishing male pigs

		Sex						
		Castrate	Immunological castrate				Entire	
Item	Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Live wt, kg		125.8^{a}	126.7^{ab}	132.1^{cd}	133.9^{d}	130.3^{cd}	129.6^{bc}	0.51
HCW, kg		92.0^{a}	90.6^{a}	93.8^{ab}	96.4^{b}	92.2^{a}	90.9^{a}	0.48
Dressing, %		73.1^{a}	71.5^{bc}	71.0^{bc}	72.0^{b}	70.7^{bc}	70.1^{c}	0.23
Fat-O-Meater								
Loin depth, cm		6.6^{ab}	6.8^{ab}	6.7^{ab}	6.7^{ab}	7.0^{b}	6.4^{a}	0.06
Fat depth, cm		1.9^{a}	1.8^{a}	1.8^{a}	1.7^{ab}	1.6^{bc}	1.4^{c}	0.03
Estimated lean, %		55.2^{a}	56.1^{a}	55.8^{a}	56.6^{ab}	57.5^{b}	58.0^{b}	0.22
Carcass measurements								
Loin eye area, cm^2		44.7^{a}	46.8^{ab}	46.8^{ab}	48.5^{b}	48.6^{b}	48.5^{b}	0.56
Backfat, cm		2.4^{a}	2.3^{a}	2.5^{a}	2.1^{a}	2.2^{a}	1.5^{b}	0.06
Right side, kg		44.7^{b}	44.1^{b}	45.7^{ab}	46.9^{a}	45.0^{b}	44.6^{b}	0.23
Skin wt, kg		3.4^{ab}	3.4^{ab}	3.2^{a}	3.5^{bc}	3.4^{ab}	3.6^{c}	0.03
Bone wt, kg		6.0^{a}	6.2^{ab}	6.3^{b}	6.4^{bc}	6.1^{ab}	6.8^{c}	0.06
Soft tissue wt, kg		35.2^{ab}	34.3^{ab}	35.7^{a}	36.1^{a}	34.8^{ab}	33.9^{b}	0.24
Soft tissue moisture, %		58.8^{a}	61.1^{b}	61.5^{bc}	62.8^{cd}	63.9^{d}	68.0^{e}	0.41
Soft tissue fat, %		24.8^{a}	22.2^{b}	21.7^{bc}	19.7^{cd}	18.1^{d}	12.6^{e}	0.53
[1]Percent lean		53.8^{a}	56.1^{b}	56.8^{b}	57.6^{bc}	59.8^{c}	64.2^{d}	0.51

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

[1]Percent lean = ((soft tissue wt - (soft tissue wt * soft tissue % fat) / right chilled side wt)*100

Table 2.4 Orthogonal polynomial contrast statement probability values of carcass characteristics of immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Live wt	0.01	< 0.01	0.77
HCW	0.17	< 0.01	0.25
Dressing	0.58	0.50	0.17
Fat-O-Meater			
Loin depth	0.51	0.29	0.90
Fat depth	0.03	0.34	0.58
Estimated percent lean	0.03	0.21	0.66
Carcass measurements			
Loin eye area	0.27	0.97	0.60
Backfat	0.19	0.65	0.04
Right side chilled wt	0.23	< 0.01	0.26
Skin wt	0.33	0.69	0.03
Bone wt	0.94	0.10	0.76
Soft tissue wt	0.51	0.03	0.76
Soft tissue wt	0.51	0.03	0.76
Soft tissue moisture	< 0.01	0.64	0.78
Soft tissue fat	< 0.01	0.51	0.63
Fat free lean	0.01	0.45	0.77

Table 2.5 The effect of GnRF immunological on pork quality and muscle composition of finishing male pigs

	Sex						
	Castrate	Immunological castrate				Entire	
Item Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Shear force, kg	2.61	2.46	2.57	2.41	2.35	2.50	0.05
Cook loss, %	21.63	22.69	22.95	22.03	22.12	23.47	0.43
pH	5.60	5.52	5.56	5.55	5.60	5.58	0.01
Objective color							
L*	55.04^{a}	55.86^{a}	54.43^{a}	54.04^{a}	53.33^{a}	48.07^{b}	0.45
a*	5.36^{a}	5.03^{ac}	5.07^{ac}	4.58^{ab}	3.94^{b}	4.55^{bc}	0.15
b*	8.84^{a}	8.79^{ab}	8.41^{ab}	7.97^{bc}	7.29^{cd}	6.20^{d}	0.17
[1]Subjective evaluations							
Color	3.00^{a}	2.81^{ab}	2.88^{a}	2.81^{ab}	2.56^{b}	3.00^{a}	0.04
Marbling	2.94^{a}	2.69^{ab}	2.44^{bc}	2.56^{ab}	2.00^{c}	2.06^{c}	0.07
Firmness	3.00	2.94	3.00	3.00	2.88	3.06	0.03
Loin composition							
Moisture, %	74.50^{a}	75.05^{ab}	75.28^{b}	75.41^{bc}	75.39^{bc}	75.85^{c}	0.08
Fat, %	2.37^{a}	2.29^{a}	1.66^{b}	1.61^{b}	1.28^{b}	1.32^{b}	0.08
Drip loss, %	2.05^{a}	2.57^{abc}	2.76^{bc}	2.98^{c}	2.33^{ab}	2.17^{ab}	0.11

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

[1]Subjective evaluations based on National Pork Producers Council standards

Table 2.6 Orthogonal polynomial contrast statement probability values of pork quality and muscle composition of immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Shear force	0.33	0.43	0.41
Cook loss	0.59	0.94	0.66
pH	0.06	0.83	0.29
Objective color			
L*	0.06	0.70	0.75
a*	0.03	0.37	0.82
b*	< 0.01	0.69	0.91
Subjective evaluations			
Color	0.09	0.14	0.89
Marbling	0.01	0.34	0.15
Firmness	0.43	0.08	0.79
Loin composition			
Moisture	0.17	0.50	0.93
Fat	< 0.01	0.38	0.27
Drip loss	0.62	0.06	0.36

Table 2.7 The effect of GnRF immunological on left side carcass cut-out values from the shoulder and loin of finishing male pigs

		Sex						
		Castrate	Immunological castrate				Entire	
Item	Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Whole shoulder, kg		11.79^{b}	11.67^{b}	11.94^{b}	12.56^{a}	11.82^{b}	11.70^{b}	0.09
% chilled side wt		26.38	26.40	26.11	26.78	26.25	26.27	0.14
Bone-in Boston, kg		3.73^{c}	3.88^{bc}	4.17^{ab}	4.45^{a}	4.21^{a}	4.35^{a}	0.05
% chilled side wt		8.33^{d}	8.81^{cd}	9.11^{bc}	9.49^{ab}	9.39^{ab}	9.75^{a}	0.09
Boneless Boston, kg		3.45^{d}	3.59^{cd}	3.80^{bc}	4.14^{a}	3.90^{ab}	3.97^{ab}	0.04
% chilled side wt		7.71^{c}	8.15^{c}	8.30^{bc}	8.82^{ab}	8.70^{ab}	8.92^{a}	0.08
Bone-in picnic, kg		4.59^{b}	4.79^{ab}	4.74^{ab}	4.91^{a}	4.58^{b}	4.53^{b}	0.04
% chilled side wt		10.28	10.76	10.38	10.49	10.19	10.17	0.08
Boneless picnic, kg		3.56^{ab}	3.70^{ab}	3.68^{a}	3.76^{ab}	3.58^{ab}	3.49^{b}	0.04
% chilled side wt		7.95	8.29	8.05	8.00	7.95	7.85	0.08
Cushion, kg		0.89^{ab}	0.91^{ab}	0.85^{ab}	0.96^{a}	0.94^{ab}	0.85^{b}	0.02
% chilled side wt		1.98	2.05	1.87	2.04	2.08	1.90	0.03
Jowl, kg		0.96^{ab}	1.04^{a}	0.99^{a}	1.00^{a}	0.99^{a}	0.82^{b}	0.02
% chilled side wt		2.15^{ab}	2.34^{a}	2.16^{a}	2.14^{a}	2.16^{a}	1.84^{b}	0.04
Whole loin, kg		12.28^{abc}	12.06^{ab}	12.53^{bc}	12.75^{c}	12.44^{abc}	11.83^{a}	0.09
% chilled side wt		27.46^{ab}	27.39^{ab}	27.42^{ab}	27.15^{ab}	27.68^{a}	26.52^{b}	0.13
Trimmed loin, kg		9.88^{a}	9.87^{a}	10.19^{ab}	10.80^{c}	10.34^{bc}	10.65^{bc}	0.08
% chilled side wt		22.08^{c}	22.43^{bc}	22.31^{bc}	22.98^{b}	23.02^{b}	23.89^{a}	0.13
Canadian back, kg		3.17^{a}	3.28^{a}	3.32^{ab}	3.58^{b}	3.53^{b}	3.53^{b}	0.03
% chilled side wt		7.08^{d}	7.46^{bcd}	7.26^{cd}	7.63^{abc}	7.88^{ab}	7.91^{a}	0.07
Tenderloin, kg		0.39^{a}	0.39^{a}	0.41^{ab}	0.44^{bc}	0.41^{ab}	0.47^{c}	0.01
% chilled side wt		0.88^{b}	0.90^{b}	0.89^{b}	0.93^{b}	0.91^{b}	1.05^{a}	0.01
Sirloin, kg		0.84^{bc}	0.79^{c}	0.90^{a}	0.96^{a}	0.93^{a}	0.89^{ab}	0.01
% chilled side wt		1.88^{bc}	1.80^{c}	1.96^{ab}	2.05^{ab}	2.07^{a}	2.00^{ab}	0.02

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

Table 2.8 Orthogonal polynomial contrast statement probability values of left side carcass cut-out values from the shoulder and loin of immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Left side chilled wt	0.13	< 0.01	0.28
Whole shoulder, kg	0.36	0.05	0.14
% chilled side wt	0.89	0.74	0.20
Bone-in Boston, kg	0.01	0.02	0.27
% chilled side wt	0.03	0.34	0.54
Boneless Boston, kg	0.01	0.03	0.12
% chilled side wt	0.01	0.48	0.23
Bone-in picnic, kg	0.35	0.18	0.12
% chilled side wt	0.07	0.85	0.31
Boneless picnic, kg	0.62	0.45	0.49
% chilled side wt	0.27	0.67	0.86
Cushion, kg	0.34	0.62	0.10
% chilled side wt	0.52	0.21	0.21
Jowl, kg	0.46	0.69	0.63
% chilled side wt	0.19	0.28	0.74
Whole loin, kg	0.16	0.07	0.79
% chilled side wt	0.66	0.43	0.43
Trimmed loin, kg	0.02	0.04	0.10
% chilled side wt	0.09	0.81	0.31
Canadian back, kg	0.01	0.60	0.14
% chilled side wt	0.02	0.16	0.33
Tenderloin, kg	0.14	0.09	0.13
% chilled side wt	0.45	0.80	0.33
Sirloin, kg	< 0.01	0.02	0.59
% chilled side wt	< 0.01	0.27	0.99

Table 2.9 The effect of GnRF immunological on left side carcass cut-out values from the ham and belly of finishing male pigs

	Sex						
	Castrate	Immunological castrate				Entire	
Item Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Whole ham, kg	10.76^{b}	10.61^{b}	10.96^{ab}	11.21^{a}	10.86^{b}	11.02^{ab}	0.06
% chilled side wt	24.07	24.13	24.00	23.91	24.21	24.73	0.12
Trimmed ham, kg	9.31^{a}	9.35^{a}	9.63^{ab}	9.96^{b}	9.61^{ab}	9.92^{b}	0.06
% chilled side wt	20.82^{b}	21.26^{b}	21.07^{b}	21.25^{b}	21.42^{ab}	22.27^{a}	0.12
Inside, kg	1.57^{a}	1.56^{a}	1.60^{a}	1.61^{a}	1.66^{ab}	1.74^{b}	0.02
% chilled side wt	3.52^{b}	3.53^{b}	3.50^{b}	3.43^{b}	3.69^{ab}	3.90^{a}	0.04
Outside, kg	2.08^{a}	2.15^{b}	2.28^{b}	2.28^{b}	2.27^{b}	2.51^{b}	0.03
% chilled side wt	4.66^{c}	4.88^{bc}	4.98^{bc}	4.87^{bc}	5.05^{b}	5.63^{a}	0.06
Knuckle, kg	1.25^{ab}	1.21^{a}	1.34^{bcd}	1.31^{bc}	1.33^{c}	1.44^{d}	0.01
% chilled side wt	2.78^{b}	2.76^{b}	2.92^{b}	2.79^{b}	2.97^{b}	3.22^{a}	0.03
Light butt, kg	0.29^{a}	0.36^{ab}	0.32^{ab}	0.34^{b}	0.30^{ab}	0.37^{c}	0.01
% chilled side wt	0.65^{b}	0.81^{a}	0.70^{ab}	0.72^{ab}	0.67^{b}	0.83^{a}	0.02
Shank meat, kg	0.69^{a}	0.69^{a}	0.73^{ab}	0.80^{b}	0.75^{ab}	0.73^{ab}	0.01
% chilled side wt	1.54	1.56	1.59	1.71	1.67	1.64	0.02
Whole belly, kg	8.40^{bc}	8.28^{c}	8.73^{ab}	8.88^{a}	8.47^{abc}	8.31^{bc}	0.06
% chilled side wt	18.78	18.80	19.16	18.94	18.81	18.64	0.10
Belly, kg	5.45^{ab}	5.11^{ab}	5.46^{ab}	5.60^{a}	5.54^{ab}	5.25^{b}	0.07
% chilled side wt	18.78	18.80	19.16	18.94	18.81	18.64	0.07
Spareribs, kg	1.63^{a}	1.9^{ab}	1.97^{ab}	1.82^{b}	1.71^{a}	1.80^{b}	0.06
% chilled side wt	3.65^{b}	4.30^{ab}	4.34^{ab}	3.88^{ab}	3.80^{b}	4.05^{a}	0.13

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

Table 2.10 Orthogonal polynomial contrast statement probability values of left side carcass cut-out values from the ham and belly and cutting yields of immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Whole ham, kg	0.09	0.01	0.41
% chilled side wt	0.90	0.45	0.77
Trimmed ham, kg	0.07	0.02	0.22
% chilled side wt	0.61	0.54	0.77
Inside, kg	0.12	0.98	0.70
% chilled side wt	0.31	0.10	0.32
Outside, kg	0.10	0.13	0.65
% chilled side wt	0.38	0.70	0.26
Knuckle, kg	0.03	0.12	0.17
% chilled side wt	0.16	0.91	0.08
Light butt, kg	0.06	0.96	0.19
% chilled side wt	0.03	0.43	0.24
Shank meat, kg	0.04	0.11	0.22
% chilled side wt	0.09	0.57	0.37
Whole belly, kg	0.28	< 0.01	0.72
% chilled side wt	0.87	0.35	0.56
Trimmed belly, kg	0.10	0.28	0.97
% chilled side wt	0.26	0.96	0.68
Spareribs, kg	0.35	0.62	0.72
% chilled side wt	0.26	0.89	0.61
Lean cutting yield	0.05	0.84	0.33
Carcass cutting yield	0.01	0.76	0.51

Table 2.11 The effect of GnRF immunological on cutting yields of finishing male pigs

		Sex						
		Castrate	Immunological castrate				Entire	
Item	Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Left side chilled wt, kg		44.65^{ab}	43.84^{a}	45.46^{bc}	46.70^{c}	44.50^{ab}	44.09^{ab}	0.24
[1]Lean cutting yield, %		61.51^{a}	62.73^{ab}	62.88^{ab}	64.08^{b}	64.01^{b}	66.09^{c}	0.26
[2]Carcass cutting yield, %		73.70^{a}	74.28^{a}	74.83^{ab}	76.12^{b}	76.33^{b}	77.87^{c}	0.27

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

[1]Lean cutting yield = ((trimmed ham + trimmed loin + Boston + picnic) / left chilled side wt)*100

[2]Carcass cutting yield = ((lean cutting yield components + trimmed belly) / left chilled side wt)*100

CHAPTER III

EFFECTS OF INCREASING LYSINE LEVELS ON FURTHER PROCESSED PRODUCT CHARACTERISTICS OF IMMUNOLOGICALLY CASTRATED MALE PIGS

ABSTRACT

The objective of this experiment was to determine if increasing lysine levels in the diets of immunologically castrated (IC) male pigs will affect further processed product characteristics when compared to physical castrates or entire males. Raw materials for this experiment were derived from a previous experiment evaluating carcass characteristics. Physical castrates, IC males, and entire males were assigned to one of four diet programs with increasing lysine levels in a step-down lysine inclusion program that culminated with the following concentrations in the late finishing diet: physical castrate - low lysine (0.7%), IC - low lysine (0.7%), IC - low/medium lysine (0.8%), IC – medium/high lysine (0.9%), IC - high lysine (1.0%), and entire - high lysine (1.0%). Bellies were injected with a cure solution to a target of 110% of original green weight, and weighed again to determine brine uptake. Hams were injected with same cure solution to a target of 130% of green weight. Cure solution was formulated for a finished product inclusion level of 1.5% salt, 0.34% phosphate, 0.05% sodium erythorbate, 0.11% sugar, and 0.014% sodium nitrate. Physical castrates had thicker (3.77 cm) bellies ($P < 0.05$) than all treatment groups, except IC males fed low/medium lysine (3.73 cm). Entire males (2.85 cm) had the thinnest ($P < 0.05$) bellies of all treatment groups. There were no differences ($P > 0.05$) in percent brine uptake for cured bellies among IC males regardless of lysine level (range 9.93% - 10.67%). Cooked yield of cured bellies were not different ($P > 0.05$) among physical castrates or IC males regardless of lysine level. Cooked yield of cured bellies from entire males (95.12%) were lower ($P < 0.05$) than cooked yield for any other treatment group. Pumped weight

differences of cured hams among treatment groups were similar to green weight differences and there were no differences ($P > 0.05$) among any treatment groups for pump uptake percentage. There were also no differences in cook loss percentages among any treatment group. Therefore, differences in cooked yield are a reflection of initial green weight. There were no differences for protein fat-free values among any treatment groups. Therefore, it can be concluded, in this population of pigs, there were no differences in further processed product characteristics among physical castrates and IC males.

INTRODUCTION

An anti-gonadotropin releasing factor (GnRF) immunological product (Improvest®; Pfizer Animal Health) is quickly gaining popularity world wide as a new technology used to take advantage of an entire male pig's ability to deposit more muscle and less fat more efficiently than a physical castrate (Campbell et al., 1989; Dunshea et al., 2001). During the early stages of growth the pig is allowed to remain an intact male. Then a few weeks prior to harvest the pig is treated with a two injection series of the immunological product to alleviate any negative boar odors that are typically associated with production of entire males (Zamaratskaia et al., 2008). Several studies have compared sensory characteristics (Font i Furnols et al., 2008; 2009), fresh pork quality characteristics (Gispert et al., 2010), and percent lean meat (Jaros et al., 2005; Fuchs et al., 2009; Rikard-Bell et al., 2009) among physical castrates, entire males and immunologically castrated (IC) males. Studies have concluded immunological castration does not affect fresh pork quality (Zamaratskaia et al. 2008; Pauly et al. 2009) however, nearly two thirds of the United States pork supply is used to produce further processed products such as cured ham or bacon. To date no studies have compared further processed product characteristics among physical castrates, IC males, and entire males. A few studies have reported an increase in

ham weight as a percentage of the carcass (Pauly et al., 2009; Gispert et al., 2010) of IC males over physical castrates but none on processing characteristics between the two sexes. The objective of this experiment was to determine if increasing dietary lysine levels would affect processing characteristics of ham and bacon manufactured from raw materials derived from IC male pigs. Another objective was to test whether further processed products made from IC males were different from those made from entire males or physical castrates.

MATERIALS AND METHODS

No approval was obtained from the University of Illinois Institutional Animal Care and Use Committee for this experiment because only carcasses were used in the experiment. Experimental procedures during the live phase of the experiment followed the guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999). Samples were obtained from a USDA FSIS inspected slaughtering facility and transported to the University of Illinois Meat Science Laboratory.

Animals

Raw materials for this experiment were derived from pigs previously described by Boler et al. (2011b). In short, 96 male pigs (PIC 337 x PIC 1050) were selected based on live weight with the two pigs per pen closest to the median pig weight selected for an in depth meat quality evaluation. Pigs were either physical castrates (n = 16), immunologically castrated (IC) males (n = 64), or entire males (n =16). Pigs were assigned by pen to one of four diet programs with increasing lysine levels fed in a conventional step-down program that culminated in the following concentrations in the late finishing diet: physical castrate - low lysine (0.7%), IC - low lysine (0.7%), IC - low/medium lysine (0.8%), IC - medium/high lysine (0.9%), IC - high lysine (1.0%), and entire - high lysine (1.0%). During the live phase portion of the experiment the IC

males were given a series of two 2 mL subcutaneous injections of an anti-gonadotropin releasing factor immunological product (Improvest®; Pfizer Animal Health). Placebo injections were not administered to the physical castrates or the entire males during either injection period. All pigs were harvested on a single day five weeks after the second injection in a U.S. FSIS inspected abattoir. The pigs were approximately 25 weeks of age at the time of harvest. After harvest, selected carcasses were transported to the University of Illinois Meat Science Laboratory, fabricated according to NAMP specifications (NAMP, 2007), and prepared for further processing.

Fresh Belly Characteristics

Bellies were measured with a ruler for length and width at the midpoint of the longitudinal and cross sectional axis. Thickness was measured at eight locations starting at the anterior end on the dorsal edge of the belly and working to the posterior end for measurements one through four. Measurements five through eight started at the anterior end of the belly along the ventral edge working toward the posterior end of the belly in a similar manner described by Stites et al. (1991). Individual location thickness and average thickness values are reported in Table 3.2. Belly flop distances were measured by draping a skin-side down belly over a stationary bar and measuring the distance between the two skin edges.

Fatty Acid Profile Analysis

Fatty acid profiles were determined using a gas chromatograph equipped with a flame ionization detector as described by Averette Gatlin et al. (2002). Iodine values (IV) were calculated using fatty acid profiles data with the following equation: IV = 16:1 (0.95) + 18:1 (0.86) + 18:2 (1.732) + 18:3 (2.616) + 20:1 (0.795) + 20:2 (1.57) + 20:3 (2.38) + 20:4 (3.19) + 20:5 (4.01) + 22:4 (2.93) + 22:5 (3.68) + 22:6 (4.64) (Meadus et al., 2010). Belly fat samples

for iodine value calculation used all three fat layers and were collected from a single location on the dorsal edge of the anterior end of the belly.

Cured Belly Manufacturing

Fresh bellies were allowed to equilibrate to approximately 4° C for at least 24 h after fabrication. During equilibration, bellies were laid flat and covered to minimize evaporative loss. After equilibration, fresh bellies were weighed to determine green weight, injected with a multi-needle injector using a Schroder Injector/Marinator, Model N50 (Wolf-Tec, Inc, Kingston, NY) with a cure solution to a target of 110% of original green weight, and weighed again to determine brine uptake. Cure solution was formulated for a finished product inclusion level of 1.5% salt, 0.34% phosphate, 0.05% sodium erythorbate, 0.11% sugar, and 0.014% sodium nitrate. Brine uptake was calculated using the following equation: $\left(\frac{Pumped\ weight - Green\ weight}{Green\ weight}\right) * 100$ Bellies were allowed to equilibrate for 48 h after injection to allow for complete distribution of the cure solution. After equilibration, bellies were weighed again to determine equilibrated belly weight, suspended by a smoking comb from the flank end and cooked in an Alkar smokehouse (Lodi, WI) to an ending internal temperature of 55° C. After cooking, cured bellies were placed in a cooler for 24 h and allowed to cool to 4° C. After chilling, bellies were weighed again to determine cooked weight. Cooked yield was calculated from the following equation: $\left(\frac{Cooked\ weight}{Green\ weight}\right) * 100.$

After manufacturing, bellies were skinned and cut at 25%, 50%, and 75% of the length of the belly from the anterior end. A 0.64 cm thick slice was collected at each location and retained for bacon proximate composition and bacon slice percent lean analysis.

Bacon Slice Percent Lean

Slices were identified based on anatomical location as blade end (25% of the length of the belly from the anterior end), middle (50%), and flank end (75%). Slices were photographed as a set per ID using a Nikon D60 camera (Nikon Instruments Inc., Melville NY) from a standardized distance from the samples. Images were converted to a black and white TIFF file in Adobe Photoshop Elements 3.0 where the individual slice outlines were selected using the magic wand tool. Image analysis was conducted using NIH image processing and analysis in Java software ImageJ (Abramoff et al. 2004). A ruler was included in each image to allow for establishment of "known distance". Threshold values were adjusted as needed within each image to account for variations in lean and fat color. Total slice length, width and area were calculated using Adobe Photoshop Elements 3.0. Secondary length [*cutaneous trunci*, (Person et al., 2005)] and secondary lean area was calculated by pixel density in ImageJ.

Cured Ham Manufacturing

Boneless 3 piece hams (NAMP #402G) were manufactured according to Boler et al. (2011a). A set of inside ham, outside ham, and knuckles originating from the same animal were stuffed into nylon nets and weighed as a set to determine green weight. After weighing, hams were injected twice through a multi-needle injector using a Schroder Injector/Marinator, Model N50 (Wolf-Tec, Inc, Kingston, NY) to a target enhancement of 30% over green weight. Cure solution was targeted to include: 1.52% salt, 0.33% sodium tripoly/hexametaphosphate blend, 0.014% sodium nitrite, and 0.05% sodium erythorbate in the finished product. Immediately after injection hams were weighed again to calculate percent cure uptake using the same calculation as for cured bellies. Hams were allowed to equilibrate for 72 h and weighed again to determine equilibrated weight. Following equilibration, hams were removed from the nylon nets,

macerated twice to increase surface area; vacuum tumbled as a set in a plastic bag for 1.5 h and stuffed into ham nettings. Hams were oriented in the stuffing net so the outside portion of the ham was positioned over the inside portion of the ham and the knuckle was placed in front of the inside/outside portion of the ham. Hams were then stuffed into the nets so the knuckle portion of the ham was near the factory clipped end and the inside/outside portion of the ham was near the hand clipped end of the netting. Netted hams were weighed just prior to loading into the smokehouse to determine stuffed weights. Hams were cooked in an Alkar smokehouse (Lodi, WI) for 10 h to an internal temperature of 65.5° C. After cooking, hams were showered with cold water and placed in a cooler at 4° C. for approximately 24 h. After chilling, hams were weighed again and cook yield was calculated with the same formula mentioned for cured bellies.

Binding Strength and Cured Color

A single ham steak was cut 2.54 cm thick at approximately 25% of the distance from the hand clipped end of the ham (the end with the inside and outside portion of the ham). The steak was standardized by cutting a section 10 cm wide perpendicular to the seam between the inside and outside portion of the ham. Hams were broken with a Texture Analyzer TA.HD Plus (Texture Technologies Corp., Scarsdale, NY/Stable Microsystems, Godalming, UK) using a 10 mm diameter cross bar at a speed of 3.33 mm/sec and a 3.81 cm platform gap. Reported values are kg of force required to break the seam.

Cured color was measured with a Minolta CR-400 utilizing a D65 light source and a 0˚ observer. Three measurements were taken at random locations across the fresh cut surface of the ham to determine objective CIE L*, a*, and b* [CIE (Commission internationale de l'eclairage), 1978] color scores. Reported values are averages of the three measurements.

Statistical Analyses

Data were analyzed with the Mixed procedure of SAS (SAS Institute, 2004) as a general linear mixed model. Pen served at the experimental unit and the fixed effect in the model was treatment (sex and lysine level combination). There were 16 pigs per treatment group with two pigs per pen being selected for analysis for a total of eight replicates per treatment. Random effects were block and the interaction between block and treatment. Means separation was conducted using the PDIFF option at the treatment level. Orthogonal polynomial contrasts were constructed to determine linear, quadratic, and cubic effects of dietary lysine on response parameters of IC males. Statistical differences were accepted as significant at $P < 0.05$ using a two-tailed test.

RESULTS AND DISCUSSION

Population summary statistics for further processed products are reported in Table 3.1.

Fresh Belly Characteristics and Fatty Acid Profiles

Fresh belly characteristics are reported in Table 3.2. As expected, physical castrates had thicker (3.77 cm) bellies ($P < 0.05$) than all treatment groups, except IC males fed low/medium lysine (3.73 cm). Entire males (2.85 cm) had the thinnest ($P < 0.05$) bellies of all treatment groups (Table 3.2). There were no differences in belly thickness among IC males with the exception of the low/medium treatment group which was thicker ($P < 0.05$) than the other IC male treatment groups (Table 3.2). In general, IC males had thinner bellies than physical castrates, but thicker bellies than entire males.

Physical castrates had wider ($P < 0.05$) flop distance (31.91 cm) than all other treatment groups with the exception of IC males fed low/medium lysine (27.10 cm). Entire males (10.75 cm) had the narrowest ($P < 0.05$) flop distances of all treatment groups (Table 3.2).

Unexplainably, IC males fed low/medium lysine had similar ($P > 0.05$) flop distances to physical castrates and were over 4 cm wider than IC males fed low lysine and medium/high lysine. Regardless of lysine level, IC males (except low/medium) had narrower flop distances than physical castrates, but wider flop distances than entire males (Table 3.2).

Differences in belly flop distance can be partially attributed to differences in fatty acid profiles. There were no differences among any treatment groups for C4:0, C6:0, C8:0, C10:0, C12:0, C17:0, C20:0, or C22:0 (Table 3.5). There were no differences among physical castrates or IC males regardless of lysine level for C14:0. C14:0 for IC males fed medium/high lysine (1.82%) was higher ($P < 0.05$) than entire males (1.55%). Palmitic acid (C16:0) comprises the largest portion of total saturated fatty acids (SFA) in a pig backfat fatty acid profile (Barton-Gade, 1987; Benz et al., 2010) and physical castrates have a higher percentage of C16:0 than entire males (Barton-Gade, 1987). The results of the current study, showed no differences ($P > 0.05$) in C16:0 percentages between physical castrates (22.44%) and entire males (21.61%), even though entire males were 0.83 percentage units lower than physical castrates. Interestingly and unexpectedly there was a linear increase ($P = 0.08$) in C16:0 percentages among IC males as dietary lysine increased (Table 3.5). Wood et al. (1985) reported fatter carcasses tended to have a higher percentage of saturated fatty acids. This provides an explanation to the 0.83 percentage unit increase of C16:0 of physical castrates over entire males as physical castrates had thicker ($P < 0.05$) bellies and more ($P < 0.05$) 10th rib back fat (Boler et al., 2011b) than entire males. The linear increase in C16:0 percentages among IC males may be explained by an increase in feed intake and a reduction in feed efficiency as lysine level increased (data not shown). It can be speculated that a greater portion of body weight gain of IC males fed low/medium, medium/high and high lysine was fat gain via *de novo* fatty acid synthesis leading to greater C16:0

percentages. Landgraf et al. (2006) explained protein deposition increases with increasing energy intake up to a genetic determined maximum. At that determined level, additional energy intake is deposited as lipid, and lean tissue deposition is decreased. Kloareg et al. (2007) reported 86% of non-essential fatty acid deposition of pig adipose is from *de novo* fat synthesis and of that 29% was C16:0. This implies the high dietary level lysine inclusion of IC males in the late finishing phase was in excess of their dietary need. There were no differences ($P > 0.05$) in C18:0 between physical castrates and IC males or between entire males and IC males. IC males fed low lysine had lower ($P < 0.05$) C18:0 percentages (8.81%) when compared to IC males fed low/medium lysine (10.58%). When summed together, IC males fed low lysine (33.86%) and entire males (34.40%) had the lowest ($P < 0.05$) percentage of total SFA when compared to the other treatment groups (Table 3.4). Unexpectedly, IC males fed low/medium lysine (37.31%) had higher total SFA ($P < 0.05$) percentages than physical castrates (34.97%), IC males fed low lysine (33.86%), and entire males. There were no differences in total SFA percentages among IC males fed low/medium lysine, IC males fed medium/high lysine, or IC males fed high lysine (Table 3.4), but there was a linear increase ($P = 0.02$) in total SFA as dietary lysine was increased in IC males (Table 3.5) .

There were no differences in C14:1, C16:1, C18:1t, C18:2t, C18:3 n3, C18:3 n6, C20:2, C20:3 n3, or C20:3 n6 among any treatment groups. There were no differences ($P > 0.05$) in C17:1 percentage between physical castrates or IC males, but IC males fed high lysine (0.40%) and entire males (0.41%) had higher ($P < 0.05$) C17:1 percentage than IC males fed medium/high lysine (Table 3). There were no differences ($P > 0.05$) in C20:1 percentages between physical castrates or IC males, but IC males fed low lysine (0.76%) and IC males fed low/medium lysine (0.70%) had higher ($P < 0.05$) C20:1 percentages than IC males fed

medium/high lysine (Table 3.4). There were also statistical differences ($P < 0.05$) among treatments for C18:1c, C18:2c, and C20:4, but these fatty acids comprise a very small percentage of the total fatty acid profile in pig adipose.

As expected, entire males had the highest ($P > 0.05$) total PUFA (16.92%) among all treatment groups (range 13.89% - 15.24%). What is interesting however, is the lack of differences ($P > 0.05$) in PUFA percentages between physical castrates and IC males. This again may be caused by overconsumption of energy by IC males after the second injection which led to *de novo* fatty acid synthesis. Iodine values (a measure of fat saturation level) was acceptable (< 72) by most standards among all treatment groups. Iodine values of entire males were lower (70.85) on a relative basis than expected, but is probably due to a lack of unsaturated fatty acid supplemented fat sources in the diet such as distiller's dried grains with solubles. There were no differences ($P > 0.05$) in iodine value among physical castrates or IC males regardless of dietary lysine inclusion. Iodine values of IC males fed low/medium (65.33), IC males fed medium/high (66.64), and IC males fed high lysine (65.97) were all lower ($P < 0.05$) or more saturated than entire males. There were no differences ($P > 0.05$) in iodine values of physical castrates (67.42), IC males fed low lysine (68.45), or entire males (70.85).

Cured Belly Characteristics

Entire males have been criticized as a source for raw materials to produce high quality bacon. This is generally attributed to fat tissue from entire males being softer and bellies losing more moisture during the manufacturing process (Wood and Enser, 1982). There were no differences ($P > 0.05$) in cured belly green weights of physical castrates (5.42 kg) when compared to other sexes, but differences were detected among the other sexes. IC males fed low lysine (5.26 kg) and entire males (5.19 kg) had lighter green weights than the other IC male

treatment groups (range 5.51 kg - 5.62 kg) (Table 3.6). Physical castrates (8.65%) took up less brine than IC males fed low lysine (10.60%), and entire males (11.35%). Entire males took up more ($P < 0.05$) brine as percentage of green weight than IC males fed medium/high (10.11%) and high lysine (9.93%). There were no differences ($P > 0.05$) in percent brine uptake among IC males regardless of lysine level (range 9.93% - 10.67%). It appears as dietary lysine level increased percent brine uptake decreased among the IC males (Table 3.6), even though there was not a linear response ($P = 0.44$) in percent brine uptake (Table 3.7). Brewer et al. (1995) reported thicker bellies retained more brine than thinner bellies when weighed after a 48 h equilibration period. The same pattern does not seem to be true in the current experiment, but entire males, who had the thinnest ($P < 0.05$) bellies, also had the highest ($P < 0.05$) cook loss percentage (12.43%) in cured bellies (Table 3.6). On the other hand, physical castrates and IC males fed low/medium lysine had the thickest bellies ($P < 0.05$) and the lowest ($P < 0.05$) cook loss percentages (physical castrates - 9.20%; IC males fed low/medium lysine - 9.01%). There were no differences in cook loss among IC males with the exception of the low/medium group that had lower cook loss percentages than the other IC male treatment groups. Cooked yield of cured bellies were not different ($P > 0.05$) among physical castrates or IC males regardless of lysine level. Cooked yield of cured bellies from entire males (95.12%) were lower ($P < 0.05$) than cooked yield of cured bellies for any other treatment group and is likely due to higher cook loss during production (Table 3.6). Cured bellies of physical castrates (46.51%) had the least amount of moisture of any treatment group when compared to cured belly moisture content of the other treatment groups. Bacon slices from entire males had the highest ($P < 0.05$) moisture content (58.83%) and lowest ($P < 0.05$) fat content (21.29%) when compared to bacon slices from other treatment groups. Bacon slice moisture content of IC males fed high lysine had

higher ($P < 0.05$) moisture content (52.13%) and lower ($P < 0.05$) fat content (30.49%) than IC males fed low lysine (49.11% moisture, 34.89% fat) and IC males fed low/medium lysine (48.79% moisture, 35.26% fat, Table 3.6). Additionally, there was a linear increase ($P = 0.01$) in bacon slice moisture and a linear decrease ($P = 0.01$) in bacon slice fat as dietary lysine of IC males was increased (Table 3.7).

Bacon Slice Percent Lean

Bacon slice percent lean data are presented in Table 3.8. Average total slice length (indication of fresh belly width) for physical castrates (17.88 cm) were shorter ($P < 0.05$) than IC males fed low/medium lysine, IC males fed medium/high lysine, IC males fed high lysine, or entire males (Table 3.8). Average total slice width (indication of fresh belly thickness) for physical castrates (3.78 cm) and IC males fed low/medium lysine (3.89 cm) had wider ($P < 0.05$) slices than IC males fed low lysine (3.51 cm) and entire males (3.47 cm). IC males fed low/medium lysine had thicker belly slices than the other IC male treatment groups (range 3.51 cm - 3.62 cm). As expected based on length and width data, IC males fed low/medium lysine had larger ($P < 0.05$) average total slice area (77.45 cm^2) when compared to IC males fed other dietary lysine inclusions. Physical castrates (73.26 cm^2) had larger total slice areas compared to entire males (67.34 cm^2). Entire males (44.66 cm^2) had larger ($P < 0.05$) average total lean areas when compared to all other treatment groups with the only exception being IC males fed low/medium lysine (42.24 cm^2). There was a linear increase ($P = 0.02$) in total lean area of bacon slices from IC males as dietary lysine level increased (Table 3.9). There were no differences ($P > 0.05$) among any treatment groups for secondary lean (*cutaneous trunci*) length or secondary lean area (Table 3.8). The lower total slice area and higher lean area measurements of entire males led to the highest ($P < 0.05$) total slice lean area as a percentage of total area

(66.86%). There was also a linear increase (P = 0.03) in total slice lean area as a percentage of total area in IC males as lysine level increased (Table 3.9).

It is important to note bellies used in this analysis were not tempered or pressed prior to analysis and may affect belly's ability to yield #1 slices and no slicing yield analysis was conducted on any of the cured bellies.

Cured Ham Characteristics

Cured ham characteristics are presented in Table 3.10. Entire males (5.58 kg) had the heaviest (P < 0.05) green weights among all treatment groups. There were no differences in green weight (P > 0.05) among IC males regardless of lysine level with the exception of IC males fed low lysine (4.79 kg) which were lighter (P < 0.05) than the other three IC male treatment groups (range 5.10 kg - 5.17 kg). Green weights of physical castrates (4.80 kg) were not different (P > 0.05) than IC males fed low lysine (4.79 kg) or IC males fed low/medium lysine (5.10 kg), but were lighter (P < 0.05) than IC males fed medium/high lysine (5.11 kg), IC males fed high lysine (5.17 kg), or entire males (5.58 kg, Table 3.10). Pumped weight differences among treatment groups were relative to green weight differences and there were no differences (P > 0.05) among any treatment groups for pump uptake percentage. There were also no differences in cook loss percentage among any treatment groups. So, differences detected in cooked yield are a reflection of initial green weight (Table 3.10). Statistical differences (P < 0.05) were detected among treatments for moisture content, but the magnitude of the differences were small. IC males fed high lysine (2.94%) and entire males (2.91%) had the lowest (P < 0.05) cured ham fat percentage among all treatments. Physical castrates (4.16%) had similar (P > 0.05) cured ham fat percentages when compared to IC males, but IC males fed low lysine (4.37%) had higher (P < 0.05) cured ham fat percentages than IC males fed low/medium lysine

(3.54%) and IC males fed medium/high lysine (3.55%). There were no differences among any treatment group for protein percentage. Also, no differences were detected for PFF values among any treatment groups.

There were no differences ($P > 0.05$) among any treatment groups for cured ham color for objective L* or a*. Statistical differences ($P < 0.05$) were detected among treatments for objective b*, but the magnitude of the differences were of little practical value. There was a linear decrease ($P = 0.02$) in b* values of cured hams from IC males as lysine level increased (Table 3.11). There were no differences ($P > 0.05$) among treatment groups for break strength. This would imply protein functionality and the ability of the available protein to bind and interact with other protein is not different among physical castrates, IC males, or entire males.

CONCLUSION

Based on this population of pigs, raw materials derived from IC males are an acceptable substitute for raw materials from physical castrates to manufacture further processed products. In general fresh bellies from IC males were thinner and softer than fresh bellies from physical castrates, but not as thin or as soft as fresh bellies from entire males. There were no differences in iodine values between physical castrates or IC male regardless of lysine level. It is important to note, pigs in this study were not fed a diet high in PUFA levels and changes in diet may impact belly quality, but those extrapolations cannot be made from this study. Cook loss percentages of cured bellies from IC males were slightly higher than physical castrates, but there were no differences in cooked yield between physical castrates and IC males. As expected, entire males had the highest cooked loss and lowest cooked yield for cured bellies among all treatment groups. There were no differences among any treatments in cooked loss, protein percentage, or protein fat-free values of cured and smoked hams. Therefore it can be concluded

that it is possible to manufacture high quality cured and smoked hams from IC males. Bacon from IC males in this population of pigs seemed to be similar to bacon from physical castrates when pigs were fed a conventional corn and soy based diet.

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Table 3.1 Population summary statistics of further processed products

	Summary Statistics					95% CL	
Item	n	Mean	Minimum	Maximum	CV, %	Lower	Upper
Fresh belly characteristics							
Length, cm	96	66.5	60.2	72.4	3.5	66.1	67.0
Width, cm	96	23.8	20.3	27.9	7.1	23.4	24.1
Average thickness, cm[1]	96	3.4	2.2	4.8	14.1	3.3	3.5
Flop distance, cm	96	22.4	5.3	58.9	50.6	20.1	24.7
Cured belly characteristics							
Green wt, kg	96	5.4	4.3	6.4	7.8	5.3	5.5
Pump wt, kg	96	6.0	4.9	7.0	7.2	5.9	6.1
Pump uptake, %	96	10.2	4.3	27.0	26.6	9.7	10.8
Equilibrium wt, kg	96	5.9	4.7	6.9	7.5	5.8	5.9
Cooked wt, kg	96	5.3	4.1	6.2	8.3	5.2	5.3
Cooked yield, %	96	96.8	93.3	111.3	2.0	96.4	97.1
Bacon composition							
Moisture, %	96	51.1	39.8	65.8	10.9	50.0	52.3
Fat, %	96	31.9	12.2	46.7	23.8	30.4	33.4
Cured ham characteristics							
Green wt, kg	96	5.1	4.0	6.5	9.5	5.0	5.2
Pump wt, kg	95	6.5	5.1	8.4	9.9	6.4	6.6
Pump uptake, %	95	27.7	14.9	37.5	11.1	27.1	28.3
Equilibrium wt, kg	96	6.1	4.7	7.9	9.7	6.0	6.3
Stuffed wt, kg	96	5.9	4.6	7.6	9.8	5.8	6.0
Cooked wt, kg	96	5.3	4.1	6.9	9.9	5.2	5.5
Cooked yield, %	96	104.9	93.9	111.8	2.8	104.3	105.5
PFF[2]	94	21.9	19.8	24.4	4.3	21.7	22.1
Break Strength, kg	94	9.7	5.8	13.9	18.6	9.3	10.0
Cured ham color							
L*	94	63.5	56.0	71.1	4.6	62.9	64.1
a*	94	11.8	7.9	16.3	11.8	11.6	12.1
b*	94	6.1	4.3	7.7	13.5	6.0	6.3
Cured ham composition							
Moisture, %	94	72.9	70.7	75.0	1.4	72.7	73.1
Fat, %	94	3.6	1.8	6.2	27.5	3.4	3.8
Protein, %	94	21.1	19.1	23.6	4.4	20.9	21.3

[1]Average thickness = average of 8 measurements at standardized locations across the belly

[2]PFF (Protein Fat-Free) = (%Protein / (100 - %Fat))*100

Table 3.2 The effect of GnRF immunological on fresh belly characteristics of finishing male pigs

	Sex						
	Physical castrate	Immunological castrate				Entire	
Item Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Length, cm	65.74^{b}	66.01^{b}	66.36^{ab}	67.74^{a}	67.60^{a}	65.80^{ab}	0.24
Width, cm	22.45^{c}	23.57^{bc}	23.46^{bc}	23.76^{b}	24.10^{b}	25.37^{a}	0.17
Thickness, cm[1]							
Location 1	2.64^{ab}	2.29^{b}	2.52^{ab}	2.40^{ab}	2.70^{a}	2.35^{ab}	0.05
Location 2	2.94^{ab}	2.73^{bc}	3.16^{a}	2.52^{cd}	2.70b^{c}	2.37^{d}	0.05
Location 3	3.95^{a}	3.18^{b}	3.65^{ab}	3.25^{b}	3.25^{b}	2.65^{c}	0.08
Location 4	4.38^{a}	3.65^{b}	4.03^{ab}	3.68^{b}	3.83^{b}	3.05c	0.07
Location 5	5.08^{ab}	4.86^{ab}	5.27^{a}	4.67^{b}	4.94^{ab}	3.83^{c}	0.08
Location 6	3.92^{ab}	3.44^{b}	3.79^{a}	3.62^{ab}	3.44^{b}	2.95^{c}	0.07
Location 7	2.92^{ab}	2.60^{bc}	2.95^{a}	2.65^{bc}	2.83^{ab}	2.48^{c}	0.05
Location 8	4.32^{ab}	3.68^{cd}	4.48^{a}	3.87^{bc}	3.52^{cd}	3.13^{d}	0.10
Average thickness	3.77^{a}	3.30^{b}	3.73^{a}	3.33^{b}	3.40^{b}	2.85^{c}	0.05
Flop distance, cm	31.91^{a}	22.62^{bc}	27.10^{ab}	22.97^{bc}	19.22^{c}	10.75^{d}	1.16

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

[1]Location 1 to 4 is from anterior to posterior position of dorsal edge of the belly; Location 5 to 8 is from the anterior to posterior position of the ventral edge of the belly

Table 3.3 Orthogonal polynomial contrast statement probability values of fresh belly characteristics of immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Length	0.01	0.65	0.29
Width	0.28	0.56	0.82
Thickness			
Location 1	0.06	0.81	0.18
Location 2	0.10	0.20	< 0.0001
Location 3	0.84	0.19	0.12
Location 4	0.72	0.45	0.06
Location 5	0.63	0.67	0.02
Location 6	0.74	0.03	0.32
Location 7	0.43	0.40	0.02
Location 8	0.26	0.01	0.09
Average thickness	0.78	0.05	< 0.01
Flop distance	0.16	0.08	0.38

Table 3.4 The effect of GnRF immunological on belly fat fatty acid profiles of finishing male pigs

	Sex						
	Physical castrate	Immunological castrate				Entire	
Item Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Butyric (4:0), %	0.12	0.10	0.09	0.06	0.09	0.10	0.014
Caproic (6:0), %	0.10	0.08	0.10	0.16	0.16	0.19	0.016
Caprylic (8:0), %	0.06	0.05	0.07	0.03	0.04	0.06	0.007
Capric (10:0), %	0.19	0.22	0.22	0.20	0.19	0.18	0.010
Lauric (12:0), %	0.15	0.14	0.12	0.13	0.13	0.11	0.005
Myristic (14:0), %	1.65^{ab}	1.66^{ab}	1.67^{ab}	1.82^{a}	1.69^{ab}	1.55^{b}	0.030
C14:1, %	0.05	0.05	0.04	0.09	0.08	0.04	0.011
Palmitic (16:0), %	22.44^{abc}	21.98^{bc}	23.81^{a}	23.47^{ab}	23.55^{a}	21.61^{c}	0.212
C16:1, %	3.25	3.75	3.22	3.33	3.28	3.33	0.084
Margaric (17:0), %	0.43	0.30	0.34	0.29	0.36	0.36	0.022
C17:1, %	0.37^{ab}	0.39^{ab}	0.38^{ab}	0.32^{b}	0.40^{a}	0.41^{a}	0.012
Stearic (18:0), %	9.44^{ab}	8.81^{b}	10.58^{a}	10.32^{ab}	10.37^{ab}	9.86^{ab}	0.222
C18:1t	0.18	0.20	0.19	0.15	0.31	0.18	0.022
C18:1c	42.97^{a}	43.45^{a}	42.45^{ab}	40.49^{c}	42.1^{abc}	41.12^{bc}	0.283
C18:2t	0.23	0.11	0.18	0.23	0.26	0.20	0.035
C18:2c	12.56^{b}	13.04^{b}	12.23^{b}	13.22^{b}	12.13^{b}	14.58^{a}	0.220
Linolenelaidic (18:3 n3), %	0.47	0.47	0.52	0.53	0.51	0.59	0.025
γ-Linolenic (18:3 n6), %	0.12	0.07	0.04	0.12	0.11	0.07	0.013
Arachidic (20:0), %	0.13	0.16	0.14	0.13	0.17	0.16	0.012
C20:1, %	0.64^{ab}	0.76^{a}	0.70^{a}	0.52^{b}	0.65^{ab}	0.67^{ab}	0.026
C20:2, %	0.50	0.49	0.47	0.48	0.50	0.57	0.016
Behenic (22:0), %	0.16	0.08	0.05	0.09	0.12	0.15	0.019
C20:3 n3, %	0.05	0.06	0.09	0.07	0.04	0.05	0.008
C20:3 n6, %	0.09	0.09	0.07	0.10	0.15	0.07	0.017
C20:4, %	0.27^{ab}	0.31^{ab}	0.25^{b}	0.26^{ab}	0.25^{b}	0.37^{a}	0.014
[1]Total SFA, %	34.97^{bc}	33.86^{c}	37.31^{a}	36.82^{abc}	36.98^{ab}	34.40^{c}	0.364
[2]Total MUFA, %	47.47^{ab}	48.65^{a}	47.00^{abc}	44.94^{c}	46.86^{abc}	45.79^{bc}	0.327
[3]Total PUFA, %	14.52^{b}	14.75^{b}	13.89^{b}	15.24^{b}	14.11^{b}	16.92^{a}	0.248
[4]UFA:SFA ratio	1.79^{abc}	1.91^{a}	1.64^{c}	1.66^{bc}	1.66^{c}	1.84^{ab}	0.027
[5]Iodine value	67.42^{ab}	68.45^{ab}	65.33^{b}	66.64^{b}	65.97^{b}	70.85^{a}	0.506

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

[1]Total SFA = (C4:0) + (C6:0) + (C8:0) + (C10:0) + (C12:0) + (C14:0) + (C16:0) + (C17:0) + (C18:0) +(C20:0) + (C21:0) + (C22:0)

[2]Total MUFA = (C14:1) + (C16:1) + (C17:1) + (C18:1t) + (C18:1c) + (C20:1) + (C22:1)

[3]Total PUFA = (C18:2t) + (C18:2c) + (C18:3 n3) + (C18:3 n6) + (C20:2) + (C20:3 n3) + (C20:3 n6) + (C20:4)

[4]UFA: SFA ratio = (total MUFA + total PUFA) / total SFA

[5]Iodine value = 16:1 (0.95) + 18:1 (0.86) + 18:2 (1.732) + 18:3 (2.616) + 20:1 (0.795) + 20:2 (1.57) + 20:3 (2.38) + 20:4 (3.19) + 20:5 (4.01) + 22:4 (2.93) + 22:5 (3.68) + 22:6 (4.64)

Table 3.5 Orthogonal polynomial contrast statement probability values of belly fat fatty acid profiles of immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Butyric (4:0)	0.68	0.55	0.54
Caproic (6:0)	0.09	0.85	0.59
Caprylic (8:0)	0.33	0.84	0.32
Capric (10:0)	0.39	0.87	0.81
Lauric (12:0)	0.57	0.26	0.42
Myristic (14:0)	0.51	0.38	0.24
C14:1	0.38	0.88	0.38
Palmitic (16:0)	0.08	0.13	0.33
C16:1	0.24	0.26	0.32
Margaric (17:0)	0.42	0.37	0.05
C17:1	0.75	0.08	0.08
Stearic (18:0)	0.09	0.12	0.33
C18:1t	0.43	0.15	0.15
C18:1c	0.12	0.09	0.10
C18:2t	0.14	0.82	0.98
C18:2c	0.45	0.78	0.07
Linolenelaidic (18:3 n3)	0.71	0.58	0.92
γ-Linolenic (18:3 n6)	0.17	0.84	0.20
Arachidic (20:0)	0.85	0.33	0.57
C20:1	0.15	0.15	0.07
C20:2	0.76	0.53	1.00
Behenic (22:0)	0.42	0.41	0.53
C20:3 n3	0.24	0.19	0.69
C20:3 n6	0.48	0.47	0.96
C20:4	0.17	0.26	0.31
Total SFA	0.02	0.07	0.28
Total MUFA	0.10	0.04	0.15
Total PUFA	0.82	0.81	0.04
UFA:SFA ratio	0.04	0.06	0.25
Iodine value	0.26	0.27	0.17

Table 3.6 The effect of GnRF immunological on cured belly characteristics of finishing male pigs

	Sex						
	Physical castrate	Immunological castrate				Entire	
Item Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Green wt, kg	5.42^{abc}	5.26^{bc}	5.62^{a}	5.57^{a}	5.51^{ab}	5.19^{c}	0.04
Pump wt, kg	5.88^{bc}	5.81^{c}	6.21^{a}	6.13^{ab}	6.05^{abc}	5.77^{c}	0.04
Pump uptake, %	8.65^{c}	10.60^{ab}	10.67^{abc}	10.11^{bc}	9.93^{bc}	11.35^{a}	0.28
Equilibrium wt, kg	5.79^{ab}	5.67^{b}	6.04^{a}	6.05^{a}	5.94^{ab}	5.63^{b}	0.04
Cooked wt, kg	5.26^{ab}	5.10^{bc}	5.50^{a}	5.39^{a}	5.33^{ab}	4.94^{c}	0.04
Cook loss, %[1]	9.20^{cd}	10.04^{bc}	9.01^{d}	10.92^{b}	10.28^{bc}	12.43^{a}	0.57
Cooked yield, %	97.03^{a}	96.96^{a}	97.91^{a}	96.76^{a}	96.74^{a}	95.12^{b}	0.20
Bacon composition							
Moisture, %	46.51^{d}	49.11^{c}	48.79^{cd}	51.44^{bc}	52.13^{b}	58.83^{a}	0.57
Fat, %	38.01^{a}	34.89^{ab}	35.26^{ab}	31.44^{bc}	30.49^{c}	21.29^{d}	0.77

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

[1]Cook loss = ((equilibrium wt - cooked wt)/equilibrium wt)*100

Table 3.7 Orthogonal polynomial contrast statement probability values of cured belly characteristics from immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Green wt	0.12	0.04	0.37
Pump wt	0.17	0.02	0.31
Pump uptake	0.44	0.86	0.76
Equilibrium wt	0.09	0.02	0.59
Cooked wt	0.20	0.03	0.22
Cook loss	0.16	0.65	< 0.01
Cooked yield	0.45	0.36	0.17
Bacon compostion			
Moisture	0.01	0.62	0.28
Fat	0.01	0.63	0.25

Table 3.8 The effect of GnRF immunological on bacon slice percent lean of finishing male pigs

		Sex						
		Physical castrate	Immunological castrate				Entire	
Item	Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Blade end								
Total slice length, cm		18.43^{b}	18.80^{ab}	19.28^{a}	19.10^{ab}	19.03^{ab}	18.43^{b}	0.11
Total slice width, cm		4.00	3.72	4.03	3.85	3.79	3.62	0.05
Total slice area, cm^2		74.27^{bc}	72.28^{bc}	81.72^{a}	75.52^{b}	74.15^{bc}	69.26^{c}	0.88
Total lean area, cm^2		32.46^{c}	33.07^{c}	39.41^{ab}	37.85^{b}	39.46^{ab}	41.35^{a}	0.72
Sec. lean length, cm		16.65	16.79	16.79	16.63	16.26	16.53	0.15
Sec. lean area, cm^2		6.59	7.73	7.86	6.97	8.51	6.72	0.26
Total slice lean area, %		43.87^{d}	45.65^{cd}	48.84^{bcd}	50.29^{bc}	53.42^{b}	60.44^{a}	1.05
Middle								
Total slice length, cm		18.02^{b}	18.77^{ab}	19.30^{a}	19.04^{a}	19.36^{a}	18.99^{ab}	0.14
Total slice width, cm		2.97^{b}	3.04^{b}	3.57^{a}	3.18^{b}	3.15^{b}	3.10^{b}	0.05
Total slice area, cm^2		67.34^{b}	66.32^{b}	74.87^{a}	67.02^{b}	66.80^{b}	64.40^{b}	0.87
Total lean area, cm^2		32.66^{c}	32.80^{c}	37.46^{ab}	34.43^{bc}	35.39^{abc}	39.14^{a}	0.60
Sec. lean length, cm		17.84	17.77	18.29	18.39	18.13	17.73	0.12
Sec. lean area, cm^2		11.74	11.27	11.86	12.51	12.28	12.00	0.28
Total slice lean area, %		48.65^{b}	49.74^{b}	50.51^{b}	51.93^{b}	53.31^{b}	61.26^{a}	0.93
Flank end								
Total slice length, cm		17.20^{b}	17.62^{a}	17.56^{a}	17.77^{a}	17.89^{a}	18.54^{a}	0.16
Total slice width, cm		4.38^{a}	3.75^{b}	4.08^{ab}	3.82^{b}	3.72^{b}	3.67^{b}	0.06
Total slice area, cm^2		78.17^{a}	70.45^{bc}	75.76^{ab}	70.00^{bc}	68.66^{c}	68.37^{c}	0.87
Total lean area, cm^2		50.58	48.44	49.86	50.12	48.37	51.84	0.74
Sec. lean length, cm		16.38	16.80	16.92	17.16	17.23	16.82	0.18
Sec. lean area, cm^2		17.96	17.81	17.30	17.06	17.62	16.04	0.37
Total slice lean area, %		43.87^{d}	45.65^{cd}	48.84^{bcd}	50.29^{bc}	53.42^{b}	60.44^{a}	0.89
Average								
Total slice length, cm		17.88^{b}	18.40^{ab}	18.71^{a}	18.63^{a}	18.76^{a}	18.66^{a}	0.11
Total slice width, cm		3.78^{ab}	3.51^{c}	3.89^{a}	3.62^{bc}	3.55^{bc}	3.47^{c}	0.04
Total slice area, cm^2		73.26^{ab}	69.68^{bc}	77.45^{a}	70.85^{bc}	69.87^{bc}	67.34^{c}	0.69
Total lean area, cm^2		38.57^{c}	38.10^{c}	42.24^{ab}	40.80^{bc}	41.07^{bc}	44.66^{a}	0.48
Sec. lean length, cm		16.95	17.12	17.33	17.39	17.21	17.03	0.11
Sec. lean area, cm^2		12.10	12.27	12.34	12.18	12.80	11.59	0.21
Total slice lean area, %		52.42^{d}	54.71^{cd}	55.15^{bcd}	57.99^{bc}	59.06^{b}	66.86^{a}	0.83

Means within a row for experimental treatments without a common superscript differ (P < 0.05)

Table 3.9 Orthogonal polynomial contrast statement probability values of bacon slice percent lean values from immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Blade end			
Total slice length	0.03	0.26	0.48
Total slice width	0.74	0.69	0.07
Total slice area	0.09	0.29	0.01
Total lean area	< 0.01	0.54	0.15
Sec. lean length	0.97	0.64	1.00
Sec. lean area	0.58	0.06	0.99
Total slice lean area	0.01	0.95	0.80
Middle			
Total slice length	0.03	0.18	0.74
Total slice width	0.03	0.05	0.01
Total slice area	0.32	0.09	0.01
Total lean area	0.12	0.28	0.08
Sec. lean length	0.09	0.79	0.51
Sec. lean area	0.30	0.40	0.76
Total slice lean area	0.30	0.94	0.91
Flank end			
Total slice length	0.36	0.81	0.70
Total slice width	0.07	0.26	0.05
Total slice area	0.06	0.65	0.02
Total lean area	1.00	0.54	0.60
Sec. lean length	0.18	0.83	0.84
Sec. lean area	0.42	0.97	0.91
Total slice lean area	0.01	0.95	0.80
Average			
Total slice length	0.03	0.28	0.89
Total slice width	0.76	0.99	< 0.01
Total slice area	0.93	0.30	< 0.01
Total lean area	0.02	0.64	0.05
Sec. lean length	0.16	0.83	0.87
Sec. lean area	0.89	0.77	0.96
Total slice lean area	0.03	0.87	0.60

Table 3.10 The effect of GnRF immunological on cured ham characteristics of finishing male pigs

	Sex						
	Physical castrate	Immunological castrate				Entire	
Item Lysine level	Low	Low	Low/Med	Med/High	High	High	SEM
Green wt, kg	4.80^{cd}	4.79^{d}	5.10^{bc}	5.11^{b}	5.17^{b}	5.58^{a}	0.05
Pump wt, kg	6.13^{cd}	6.09^{d}	6.57^{b}	6.48^{bc}	6.63^{b}	7.16^{a}	0.07
Pump uptake, %	27.61	26.97	28.70	26.73	28.23	28.08	0.32
Equilibrium wt, kg	5.80^{cd}	5.72^{d}	6.16^{bc}	6.12^{bc}	6.23^{b}	6.75^{a}	0.06
Stuffed wt, kg	5.58^{cd}	5.57^{d}	5.95^{b}	5.89^{bc}	6.04^{b}	6.56^{a}	0.06
Cooked wt, kg	5.03^{cd}	5.01^{d}	5.35^{b}	5.29^{bc}	5.46^{b}	5.91^{a}	0.05
Cook loss, %[1]	9.92	10.07	9.96	10.12	9.52	9.88	0.26
Cooked yield, %	104.69^{ab}	104.47^{ab}	104.93^{ab}	103.55^{b}	105.69^{ab}	105.93^{a}	0.30
Moisture, %	72.27^{d}	72.22^{d}	72.78^{cd}	72.92^{bc}	73.38^{ab}	73.69^{a}	0.10
Fat, %	4.16^{ab}	4.37^{a}	3.54^{b}	3.55^{b}	2.94^{c}	2.91^{c}	0.10
Protein, %	21.03	21.17	21.17	21.10	20.97	21.16	0.10
PFF[2]	21.94	22.13	21.95	21.88	21.60	21.80	0.10
Cured color							
L*	63.32	63.53	64.34	64.16	62.78	63.00	0.30
a*	11.98	11.99	11.59	11.56	11.87	12.09	0.14
b*	6.13^{ab}	6.51^{a}	6.19^{ab}	6.19^{ab}	5.74^{b}	6.11^{ab}	0.09
Break strength, kg	10.73	9.16	9.28	9.45	9.57	9.64	0.19

Means within a row for experimental treatments without a common superscript differ ($P < 0.05$)

[1]Cook loss = ((stuffed weight-cook wt)/stuffed wt)*100

[2]PFF (Protein Fat-Free) = (%Protein / (100 - %Fat))*100

Table 3.11 Orthogonal polynomial contrast statement probability values of cured ham characteristics from immunologically castrated male pigs fed increasing lysine levels

	Response parameter		
Item	Linear	Quadratic	Cubic
Green wt	0.01	0.21	0.42
Pump wt	0.01	0.22	0.17
Pump uptake	0.60	0.89	0.04
Equilibrium wt	0.01	0.18	0.25
Stuffed wt	0.01	0.34	0.23
Cooked wt	0.01	0.42	0.19
Cook loss	0.15	0.28	0.31
Cooked yield	0.53	0.31	0.15
Moisture	< 0.01	0.77	0.42
Fat	< 0.0001	0.58	0.11
Protein	0.51	0.76	1.00
PFF	0.11	0.85	0.74
Cured color			
L*	0.43	0.12	0.94
a*	0.81	0.32	0.98
b*	0.02	0.79	0.40
Break strength	0.53	0.90	0.90

CHAPTER IV

EFFECTS OF ENDING LIVE WEIGHT CATEGORY AND HARVEST TIME POST-SECOND INJECTION ON CARCASS CUTTING YIELDS AND BACON CHARACTERISTICS OF IMMUNOLOGICALLY CASTRATED MALE PIGS

ABSTRACT

Live weights of finishing pigs can be variable within a finishing barn near the time of harvest, therefore, it is common to market pigs over a period of time. This allows lighter pigs more time to gain weight and approach a desired end point. Use of immunological castration late in life to control boar taint, as an alternative to physical castration early in life, increases cutting yields of finishing male pigs when compared to physical castrates. Because of common marketing strategies, it is important for advantages in cutting yields to span a broad spectrum of harvest ages and live weights. The primary objectives in this study were to evaluate carcass cutting yields, pork quality, belly quality, and bacon processing characteristics of immunologically castrated (IC) male pigs fed a moderate level of distiller's dried grains with solubles (DDGS), harvested at either 4 weeks (early harvest group) or 6 weeks (late harvest group) post second injection, and classified as light, median, or heavy ending live weight category. A total of 156 male pigs (physical castrates or IC males) were selected from a population of 1200 finishing pigs. Data were analyzed with the Mixed procedure of SAS as a split-split plot design. Live weights of IC males were 3.60 kg heavier ($P = 0.03$) than physical castrates when harvested at 4 weeks post-second injection and 7.52 kg heavier ($P < 0.0001$) than physical castrates when harvested at 6 weeks post-second injection. Because of a lack of interaction ($P > 0.05$) between sex and time of harvest post-second injection some response variables were pooled. Hot carcass weights were not different ($P = 0.57$) between physical

castrates (91.98 kg) and IC males (92.52 kg). There was a 2.77 percentage unit decrease ($P < 0.001$) in dressing percentage of IC males (71.78%) compared to physical castrates (74.55%). Lean cutting yields of IC males were 2.62 percentage units higher ($P < 0.0001$) than physical castrates and carcass cutting yields were 2.27 percentage units higher ($P < 0001$) for IC males when compared to physical castrates. There were no differences between IC males and physical castrates for shear force ($P = 0.09$), ultimate pH ($P = 0.57$), objective color ($P \geq 0.31$), subjective color score ($P = 0.64$), or drip loss ($P = 0.30$). Bellies from IC males were thinner ($P = 0.01$) and had narrower belly flops ($P < 0.0001$) than bellies from physical castrates. There were no differences ($P = 0.74$) in cured belly cooked yield between IC males and physical castrates. Overall, immunological castration improved cutting yields, did not affect pork quality, made fresh bellies thinner, and did not affect cured belly characteristics when pigs were fed a moderate level of DDGS during the finishing phase of production.

INTRODUCTION

Improvest® (Pfizer Animal Health, Kalamazoo, MI) is a swine immunological product that stimulates the pig's immune system to produce antibodies to gonadotropin releasing factor (GnRF), temporarily blocking its activity. Immunologically blocking the signal from GnRF to the anterior pituitary decreases the production of testicular steroids (Zamaratskaia et al., 2008) thus eliminating boar taint issues. Reduction of boar taint with immunological castration has been proven hormonally (Dunshea et al., 2001), with consumer sensory panels (Font i Furnols et al., 2008), and trained panels (Font i Furnols et al., 2009). Reported data has also consistently shown an improvement in feed efficiency (Dunshea et al., 2001; Fàbrega et al., 2010), no differences in pork quality parameters (Pauly et al., 2009; Gispert et al., 2010), an increase in

carcass leanness (Jaros et al., 2005; Fuchs et al., 2009) and higher cutting yields (Boler et al., 2011b) of immunologically castrated (IC) males when compared to physical castrates.

Because of variation in live weights of pigs within a finishing barn near the time of harvest, it is common practice to market pigs over a period of time (DeDeker et al., 2005). This allows slower growing pigs more time to gain weight and come closer to the desired compositional end point. It is important to understand if the advantages of immunological castration persist over the entire marketing period. Therefore, the primary objectives in this study were to evaluate carcass cutting yields, pork quality, belly quality, and bacon processing characteristics of IC male pigs fed a moderate level of distiller's dried grains with solubles (DDGS), harvested at either 4 weeks (early harvest group) or 6 weeks (late harvest group) post second injection, and classified as light, median, or heavy ending live weight category.

MATERIALS AND METHODS

No approval was obtained from the University of Illinois Institutional Animal Care and Use Committee for this experiment because only carcasses were used in the experiment. Experimental procedures during the live phase of the experiment followed the guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010). Carcasses were obtained from a USDA FSIS harvesting facility and then transported to the University of Illinois Meat Science Laboratory.

Allotment and Diet Schedule

Pigs selected for the study were a subset of animals used in a large commercial feeding study involving 1200 total finisher pigs (PIC 337 x PIC C-22, Pig Improvement Company, Hendersonville, TN). Initially, at one week of age, pigs were randomly assigned to one of two sexes (physical castrate or IC male). Pigs designated for physical castration were surgically

castrated within 10 d of birth. Both sexes were weaned at three weeks of age and fed the same nursery diet until they were placed in the grower/finisher barn at six weeks of age. At six weeks of age, pigs were switched to different diets based on sex. Both sexes were fed a step-down lysine program, but IC males were fed a diet higher in lysine than physical castrates throughout the grower and finisher phase of the trial and culminated in physical castrates being fed 0.83% lysine in the late finishing phase and IC males being fed 1.00% lysine during the late finishing phase (Table 4.1). Boler et al. (2011b) reported IC males fed a diet higher in lysine than physical castrates showed improved carcass cutting yields and implied the lysine requirement to maximize carcass cutability of IC males is higher than physical castrates. Both diets contained 20% DDGS until the pigs were 21 weeks of age. At that time the DDGS level was reduced to 10% and fed at that level until harvest.

At 15 weeks of age, the IC males received the first of two 2 mL subcutaneous injections of an anti-gonadotropin releasing factor (anti-GnRF) immunological product (Improvest®; Pfizer Animal Health, Kalamazoo, MI). The second dose was administered to the IC males at 19 weeks of age. Both sexes were harvested based on selection criteria over a 2 week period at either 23 weeks (4 weeks post second injection) or 25 weeks (6 weeks post second injection) of age. No placebo injections were given to the physical castrates during either injection period.

Animal Selection

Pigs were housed in pens of approximately 25 pigs of like sex per pen. In total, there were 13 physical castrate pens and 13 IC male pens. Selection criteria were based on sex and ending live weight. After the final evaluation period, all pigs were individually weighed (without a fast) and ranked based on live weight within its respective pen. Initially, the heaviest 60% of the pigs within a pen (15 per pen) were designated for harvest at 23 weeks of age and

classified as the early harvest group. Within the early group, the second heaviest, second lightest, and median weight pig per pen were selected (3 per pen) for meat quality analysis and harvested at a U.S. FSIS inspected harvest facility. Two weeks later, the remaining 40% of the initial group were weighed again and classified as the late harvest group. The second heaviest, second lightest, and median weight pig from each pen (n = 78) were again designated for meat quality analysis and harvested in the same facility as the early harvest group. A total of 156 pigs were selected for the trial (13 pigs per sex within harvest group and weight classification). At harvest, HCW were collected along with 10th rib loin depth, and 10th rib fat depth on the right side of the carcass using a Fat-O-Meater system (Fat-O-Meater measurements, SFK Technology Fat-O-Meater, Herley, Denmark). Loin depth and fat depth measurements were used to calculate estimated percent carcass lean. After a 24 h chill period, the right side of each carcass was transported to the University of Illinois Meat Science Laboratory for further analysis.

Carcass Fabrication

At four days postmortem, the right side of each chilled carcass was initially fabricated into ham, loin, belly (spareribs left on), whole shoulder (neck bones removed) and jowl to comply with Institutional Meat Purchase Specifications (IMPS) as described by the North American Meat Processors Association (2010). Each primal piece was weighed again before further fabrication into subprimal cuts. Because of the variability in live weight and HCW across treatments, carcass cut-out data were also expressed as a percentage of chilled side weight.

Shoulder The whole shoulder was fabricated into a modified IMPS #404 skinned shoulder, where the picnic portion was skinned also. The Boston butt was separated from the picnic to form a IMPS #406 bone-in Boston butt and a modified skinned IMPS #405 bone-in picnic shoulder. Each piece was then boned out to meet the specifications of IMPS #406A

boneless Boston butt and a IMPS #405A boneless picnic shoulder. The boneless picnic shoulder was further fabricated by removing the *triceps brachii* and weighing the cushion (IMPS #405B).

Loin Skin-on bone-in loins were skinned to meet the specifications of a IMPS #410 loin. Trimmed loins were weighed and fabricated into a IMPS #414 Canadian back, IMPS #415A tenderloin (side muscle off), and the sirloin end. Identities of the Canadian back loins were retained for later evaluation of pork quality parameters.

Ham Hams were cut to meet the specification of a IMPS #401 and designated as a whole ham. Whole hams were skinned and trimmed of excess fat to meet the specification of IMPS #402 to determine trimmed ham weight. Trimmed hams were fabricated into five separate pieces: inside ham (IMPS #402F), outside ham (IMPS #402E), knuckle (IMPS #402H), shank portion, and light butt. The inside, outside, and knuckle were completely denuded of fat.

Belly The whole spareribs-in belly was fabricated into a IMPS #408 belly (teat line removed and flank end squared) and IMPS #416 spareribs.

Cutting Yields

Bone-in lean cutting yield was calculated with the following equation: lean cutting yield = $\frac{(trimmed\ ham+trimmed\ loin+Boston\ butt+picnic)}{chilled\ right\ side\ wt} * 100$ and carcass cutting yield was calculated with the following equation: carcass cutting yield = $\frac{(lean\ cutting\ yield\ components+trimmed\ belly)}{chilled\ right\ side\ weight} * 100.$

Pork Quality

Pork quality measurements for ultimate pH, objective color, subjective color, marbling, and firmness scores, and drip loss were conducted by trained University of Illinois meat science

laboratory personnel. Measurements were collected after fabrication on boneless Canadian back loins (NAMP #414) cut at the area of the 10th rib. Ultimate pH was measured using a hand held pH star probe fitted with a glass electrode (SFK Technologies Inc., Cedar Rapids, IA; 2 point calibration- pH 4 and 7). Objective CIE L*, a*, and b* (CIE (Commission internationale de l'eclairage), 1978) values were collected with a Minolta CR-400 utilizing a D65 light source and a 0° observer and an aperture size of 8 mm. Subjective color and marbling scores (NPPC, 1999) and firmness scores (NPPC, 1991) were conducted by a single individual according to standards established by the National Pork Producers Council. Loin proximate composition was determined in the same manner described by Novakofski et al. (1989). Water holding capacity was evaluated using the drip-loss method where a 1.25 cm thick chop was suspended from a fish hook in a Whirl-pak bag for approximately 24 h at 4° C. Chops were weighed prior to and immediately after suspension. Results were reported as a percentage of weight loss.

Warner-Bratzler Shear Force

Chops for shear force were cut 2.54 cm thick from the longissimus muscle posterior to the area of the 10th rib. Chops were vacuum packaged, stored at 4° C, and aged until 14 days post mortem. At the end of the aging period, chops were frozen and held until further analysis. Twenty-four hours prior to analysis, chops were removed from the freezer and placed in a cooler at 4° C to thaw. Chops were trimmed of excess fat and cooked on a Farberware Open Hearth grill (Model 455N, Walter Kidde, Bronx, NY). Chops were cooked on one side to an internal temperature of 35° C, flipped, and cooked to a final internal temperature of 70° C. Internal temperature was monitored using copper-constantan thermocouples (Type T, Omega Engineering, Stanford, CT) connected to a digital scanning thermometer (Model 92000-00 Barnant Co., Barington, IL). Next, chops were allowed to cool to 25° C and four 1.25cm

diameter cores were removed parallel to the orientation of the muscle fibers. Cores were sheared using a Texture Analyzer TA.HD Plus (Texture Technologies Corp., Scarsdale, NY/Stable Microsystems, Godalming, UK) with a blade speed of 3.3 mm/sec and a load cell capacity of 100 kg. Shear force was determined on each of the four cores. Shear force was reported as the average of the four cores. Cook loss was determined by weighing chops used for shear force immediately before and after cooking. Reported values are percentage weight lost during cooking.

Fresh Belly Characteristics

Bellies were measured with a ruler for length and width at the midpoint of the longitudinal and cross sectional axis. Thickness was measured at eight locations starting at the anterior end on the dorsal edge of the belly and working to the posterior end for measurements one through four. Measurements five through eight started at the anterior end of the belly along the ventral edge working toward the posterior end of the belly in a similar manner described by Stites et al. (1991). Belly flop distances were measured by draping a skin-side down belly over a stationary bar and measuring the distance between the two skin edges.

Fatty Acid Profile Analysis

Fatty acid profiles were determined using a gas chromatograph equipped with a flame ionization detector as described by Averette Gatlin et al. (2002). Iodine values (IV) were calculated using fatty acid profile data with the following equation: IV = 16:1 (0.95) + 18:1 (0.86) + 18:2 (1.732) + 18:3 (2.616) + 20:1 (0.795) + 20:2 (1.57) + 20:3 (2.38) + 20:4 (3.19) + 20:5 (4.01) + 22:4 (2.93) + 22:5 (3.68) + 22:6 (4.64) (Meadus et al., 2010). Belly fat samples for iodine value calculation used all three fat layers and were collected on the dorsal edge of the anterior end of the belly.

Cured Belly Manufacturing

Fresh bellies were allowed to equilibrate to approximately 4° C for at least 24 h after fabrication. During equilibration, bellies were laid flat and covered to minimize evaporative loss. After equilibration, fresh bellies were weighed to determine green weight, injected with a multi-needle injector using a Schroder Injector/Marinator, Model N50 (Wolf-Tec, Inc, Kingston, NY) with a cure solution to a target of 110% of original green weight, and weighed again to determine pump uptake. Cure solution was formulated for a finished product inclusion level of 1.5% salt, 0.34% phosphate, 0.05% sodium erythorbate, 0.11% sugar, and 0.014% sodium nitrate. Pump uptake was calculated using the following equation:

$\left(\frac{Pumped\ weight - Green\ weight}{Green\ weight}\right) * 100$ Bellies were allowed to equilibrate for 48 h after injection to allow for complete distribution of the cure solution. After equilibration, bellies were weighed again to determine equilibrated belly weight, combed from the flank end and cooked in an Alkar smokehouse (Lodi, WI) to an ending internal temperature of 55° C. After cooking, cured bellies were placed in a cooler for 24 h and allowed to cool to 4° C. After chilling, bellies were weighed again to determine cooked weight. Cooked yields were calculated with the following equation:

$\left(\frac{Cooked\ weight}{Green\ weight}\right) * 100.$

After manufacturing, bellies were peeled and cut at 25%, 50%, and 75% of the length of the belly from the anterior end. A 0.64 cm thick slice was collected at each location and retained for bacon proximate composition.

Statistical Analyses

Data were analyzed with the Mixed procedure of SAS (SAS Institute, 2004) as a split-split plot design. Pen served at the experimental unit and the fixed effects in the model were sex,

weight category, time of harvest post-second injection, and the interaction of sex with weight category, sex with time of harvest post-second injection, and the three way interaction of sex with weight category and time of harvest post-second injection. Block (BW at the time of allocation to treatment) served as the random variable. The whole plot of sex (physical castrate or IC male) was tested with the interaction of block and sex. The split plot was harvest group (early or late) and block x sex x harvest group served as the error term. Ending live weight category (light, median, heavy) was the split-split plot and was tested with block x sex x harvest group x ending live weight category as the error term. Statistical differences were accepted as significant at $P < 0.05$ using a two-tailed test.

RESULTS AND DISCUSSION

Carcass Characteristics

Pigs were selected within a harvest period to evaluate pigs that represent a heavy, light, and median pig. Over both harvest periods, selection criteria were met and pigs designated as the heavy category (131.37 kg) were heavier ($P < 0.001$) than pigs in the median category (126.07 kg) which were heavier ($P < 0.001$) than pigs designated as the light category (121.03 kg, Table 4.3). There was also an expected difference in live weights between harvest groups. Pigs in the early group (124.54 kg) were lighter ($P < 0.001$) than pigs harvested in the late group (127.77 kg) (Table 4.2). Ending live weights, averaged over both harvest times post-second injection, of the IC males were 5.5 kg heavier ($P < 0.01$) than physical castrates (Table 4.2). Ending live weights of the IC males in the early group (126.34 kg) were heavier ($P = 0.03$) than physical castrates in the early group (122.74 kg); and ending live weights of IC males in the late group (131.53 kg) were heavier ($P < 0.001$) than physical castrates in the late group (124.01 kg). Additionally, IC males in the late group were 5.19 kg heavier ($P < 0.001$) than IC males

harvested in the early group (Table 4.2). The ending live weight advantage of IC males over physical castrates agrees with several studies reporting ending live weights at different end points (Pauly et al., 2009, $\bar{x}$ = 107.1 kg; Fàbrega et al., 2010, $\bar{x}$ = 120.9 kg; Boler et al., 2011a, $\bar{x}$ = 129.7 kg). Despite the increase in ending live weights, hot carcass weights were not different (P = 0.57) between physical castrates (91.98 kg) and IC males (92.52 kg, Table 4.2). This is likely due the presence of testicles and the removal of scrotal skin and fat associated with IC males and provides some explanation for the 2.77 percentage unit decrease (P < 0.001) in dressing percentage of IC males (71.78%) compared to physical castrates (74.55%, Table 4.2). Liver weights have also been reported as heavier in IC males when compared to physical castrates (Pauly et al., 2009). The magnitude of difference in dressing percentages between IC males and physical castrates in the current study is greater than other studies (Pauly et al., 2009, 1.2 percentage units; Gispert et al., 2010, 2.11 percentage units). Ending live weights of pigs in the current study were weighed 48 h prior to harvest and without a fasting period. Dunshea et al. (2001) reported a 9% increase in ADFI of 26 week old IC males compared to physical castrates. Increased gut fill coupled with testicle weights, scrotal skin, and fat may account for some of the differences in dressing percentages between IC males and physical castrates. As expected however, pigs classified as the heavy group had heavier hot carcass weights than pigs classified as median, which had heavier hot carcass weights than pigs classified as light (Table 4.3). There were no differences (P = 0.61) in dressing percentage among any weight categories or an interaction (P = 0.14) between sex and ending live weight category (Table 4.3).

There were no differences (P = 0.09) in loin depths of IC males (61.0 mm) and physical castrates (62.8 mm), but IC males had less (P = 0.01) 10th rib backfat than physical castrates (Table 4.2). Estimated carcass lean was not different (P = 0.09) between IC males (56.25%) and

physical castrates (55.65%, Table 4.2). Researchers have reported an average advantage ($P \leq 0.05$) of carcass leanness of IC males over physical castrates to be 0.67 percentage units (Jaros et al., 2005; Fuchs et al., 2009; Pauly et al., 2009; Rikard-Bell et al., 2009; Gispert et al., 2010) with various methods of evaluation. Therefore, the difference in carcass leanness in the current study (0.6 percentage units) between IC males and physical castrates is comparable to previous experiments (Table 4.2). However, Boler et al. (2011b) reported the Fat-O-Meater underestimates carcass leanness of IC males and the magnitude of the differences between IC males and physical castrates is likely much larger when leanness is determined by fat-free lean determination.

Carcass Fabrication

Cut-out values are presented in tables 4.4, 4.5, 4.6 and 4.7. Whole shoulders, bone-in Boston butts, boneless Boston butts, bone-in picnics, boneless picnics, and jowls from IC males were heavier ($P \leq 0.02$) than shoulder components of physical castrates. Boneless Boston shoulders from IC males harvested at 6 weeks post-second injection were heavier than boneless Boston shoulders from IC males harvested at 4 weeks post-second injection and both were heavier ($P < 0.0001$) than boneless Boston shoulders from physical castrates (Table 4.4). There were no differences ($P = 0.07$) in cushion (*triceps brachii*) weights (Table 4.4). When expressed as a percentage of chilled side weights, whole shoulders, bone-in Boston butts, boneless Boston butts, bone-in picnics, and boneless picnics made up a larger portion ($P \leq 0.02$) of the IC male carcasses than physical castrate carcasses. There were no differences ($P = 0.09$) in cushions as a percentage of chilled side weights between IC males and physical castrates (Table 4.4). Jowls of IC males made up a smaller percentage ($P < 0.01$) of chilled IC male carcass weights than of physical castrate carcasses.

There were no significant interactions ($P < 0.05$) between sex and time of harvest post-second injection for any loin primal or subprimal cuts (Table 4.4). Whole loins ($P = 0.22$), trimmed loins ($P = 0.07$), and backribs ($P = 0.37$) were not different between IC males and physical castrates, but each of the loin components were heavier ($P \leq 0.03$) in IC males than in physical castrates (Table 4.4). When expressed as a percentage of chilled side weights, whole loins (skin-on, untrimmed, and bone-in) of physical castrates made up a larger percentage ($P = 0.02$) of chilled side weights than IC males. This is probably due in part to thicker backfat depths of physical castrates. Percentages of trimmed loins were not different ($P = 0.07$) between physical castrates and IC males. Canadian back loins, tenderloins, and sirloins each made up a larger percentage ($P \leq 0.04$) of chilled side weight in IC males than in physical castrates. Percentages of chilled side weights were not different ($P = 0.40$) for backribs (Table 4.4).

There were, however, significant interactions ($P < 0.05$) among pigs in different ending live weight categories (Table 4.5). Physical castrates categorized as light and median ending live weight category had lighter tenderloins and comprised a lower percentage of chilled side weights than tenderloins from IC males categorized as light and median. There were no differences in tenderloin weights between physical castrates categorized as heavy and IC males categorized as heavy. Backribs from physical castrates classified as median were 0.05 kg heavier ($P = 0.05$) than backribs from IC males classified as median (Table 4.5).

There were no significant interactions ($P < 0.05$) between sex and time of harvest post-second injection for any ham primal or subprimal cuts (Table 4.6). Whole ham weights were not different ($P = 0.10$) between IC males and physical castrates, but trimmed hams, insides, outsides, knuckles, light butts and shanks were all heavier ($P \leq 0.04$) in IC males when compared to physical castrates (Table 4.6). When expressed as a percentage of chilled side weights, whole

hams, trimmed hams, and all five components of the ham (inside, outside, knuckle, light butt, and shank) were higher ($P \leq 0.04$) in IC males when compared to physical castrates (Table 4.6).

There were, however, significant interactions ($P < 0.05$) among pigs in different ending live weight categories (Table 4.7). Physical castrates categorized as light ending live weight category had outside ham muscles that were 0.21 kg lighter ($P < 0.01$) and comprised a lower percentage of chilled side weights than outside ham muscles from IC males categorized as light and. There were no differences in outside ham muscle weights between physical castrates categorized as median and IC males categorized as median or between physical castrates categorized as heavy and IC males categorized as heavy (Table 4.5).

There were no significant interactions ($P < 0.05$) between sex and time of harvest post-second injection for any belly cuts (Table 4.6). Whole bellies ($P = 0.44$), trimmed bellies ($P = 0.23$), and spareribs ($P = 0.12$) weights were not different between IC males and physical castrates (Table 4.6). When expressed as a percentage of chilled side weights whole bellies ($P = 0.07$) and spareribs ($P = 0.08$) were similar between IC males and physical castrates. As expected, trimmed bellies from IC males (11.54%) made up a smaller ($P = 0.04$) percentage of chilled side weights than trimmed bellies from physical castrates (11.87%).

Cutting Yields

There were no interactions between sex and harvest time ($P = 0.99$, (Table 4.8) or between sex and weight category ($P = 0.43$, (Table 4.9) or the three-way interaction ($P = 0.84$) for lean cutting yields. There were also no interactions between sex and harvest time ($P = 0.49$, Table 4.8) or between sex and weight category ($P = 0.66$, Table 4.9) or the three-way interaction ($P = 0.28$) for carcass cutting yields. However, IC males had heavier boneless lean product weights regardless of time of harvest post-second injection when compared to physical castrates

in all of the major primal cuts (Boston butt, picnic, loin, and ham) except the belly (Table 4.4 and 4.6). Those advantages translated into higher ($P < 0.0001$) lean cutting yields and higher carcass cutting yields ($P < 0.0001$) of IC males when compared to physical castrates regardless harvest time post-second injection (Figure 4.1). Lean cutting yields of IC males harvested at 4 weeks post-second injection were 2.61 percentage units higher than physical castrates and carcass cutting yields were 2.47 percentage units higher than physical castrates (Table 4.8). Lean cutting yields of IC males harvested at 6 weeks post-second injection were 2.63 percentage units higher than physical castrates and carcass cutting yields were 2.06 percentage units higher than physical castrates (Table 4.8). This resulted in a lean cutting yield advantage of IC males being 2.62 percentage units higher ($P < 0.0001$) than physical castrates and carcass cutting yields being 2.26 percentage units higher ($P < 0001$) than physical castrates when averaged over both harvest times. Boler et al. (2011b) reported an increase in cutting yields for IC males as dietary lysine is increased in the diet and the increase culminated with IC males having an advantage of 2.5 percentage units advantage in lean cutting yields and a 2.4 percentage unit advantage in carcass cutting yields over physical castrates (fed a diet lower in lysine) when IC males were fed closer to their assumed dietary lysine requirement. An advantage in cutting yields of nearly 2.5 percentage units of IC males over physical castrates reported in previous studies was detected in the current study for pigs harvested at 4 wks post-second injection and persisted in pigs harvested at 6 weeks post-second injection. Lean cutting yields of IC males in the light category (65.68%), median category (64.65%), and heavy category (64.52%) were heavier ($P \leq 0.001$) when compared to lean cutting yields of light physical castrates (62.52%), median physical castrates (62.57%), or heavy physical castrates (61.90%) within their respective weight categories (Table 4.9). Carcass cutting yields of IC males in the light category (76.99%), median

category (76.21%), and heavy category (76.27%) were heavier ($P \leq 0.001$) when compared to carcass cutting yields light physical castrates (74.48%), median physical castrates (74.32%), or heavy physical castrates (73.88%) within their respective weight categories (Table 4.9).

Pork Quality

The only significant interactions ($P < 0.05$) between sex and time of harvest post-second injection for pork quality characteristics were objective L* for loin lightness ($P = 0.01$) and objective b* for loin blueness ($P = 0.04$) (Table 4.10). The only significant interactions ($P < 0.05$) between sex and ending live weight category were for ultimate pH, objective L*, and objective a* (Table 4.11). Nearly every reported study comparing IC males to physical castrates has documented few practical differences in pork quality attributes. In the current study, there were no differences between IC males and physical castrates for shear force ($P = 0.09$), ultimate pH ($P = 0.57$), a* ($P = 0.33$), subjective color score ($P = 0.64$), or drip loss ($P = 0.30$) (Table 4.10). Cook loss of chops from physical castrates (21.30%) was less than cook loss of chops from IC males (23.47%).

Objective L* values for physical castrates harvested in the early group were 1.55 L* units lower (darker) than IC males harvested in the early group, but L* values for physical castrates harvested in the late group were 1.45 L* units higher (lighter) than L* values for IC males harvested in the late group (Table 4.10). Objective b* values for physical castrates harvested in the early group were 0.20 b* units lower (more blue) than IC males harvested in the early group, but b* values for physical castrates harvested in the late group were 0.65 b* units higher (more yellow) than b* values for IC males harvested in the late group (Table 4.10). Objective L* values for physical castrates categorized as light were higher (lighter in color) than objective L* values for IC males categorized as light, but objective L* values for physical castrates

categorized as median were lower (darker in color) than IC males classified as median. Even so the magnitude of the differences were only 2.09 L* units between the higher and lowest L* value and so is of little practical value (Table 4.11).

Subjective marbling scores (P = 0.03) and objective extractable lipid content (P = 0.02) were less in IC males than physical castrates (Table 4.10). Other studies have reported similar (P > 0.05) marbling scores between physical castrates and IC males. Gispert et al. (2010) reported no differences in marbling scores of the semimembranosus muscle of IC males (2.07%) or physical castrates (2.47%). Boler et al. (2011a) reported no differences in extractable lipid content of the longissimus muscle between IC males and physical castrates when fed the same diet, but did show a decrease in extractable lipid in IC males as dietary lysine increased.

Fresh Belly Characteristics and Fatty Acid Profiles

There were no differences (P = 0.10) in fresh belly length between IC males and physical castrates, but IC males (24.55 cm) had wider (P = 0.02) bellies than physical castrates (23.73 cm) (Table 4.12). Bellies from IC males were thinner (P = 0.01) and had narrower belly flops (P < 0.0001) than bellies from physical castrates (Table 4.12). Fatty acid profiles are reported in table 4.14 and 4.15. IC males had higher (P < 0.01) total MUFA and PUFA concentrations than physical castrates when averaged over both harvest times. It is generally accepted that leaner pigs have a higher percentage of unsaturated fatty acids. IC males in the current study had 1.35 mm less backfat at the 10th rib and likely explains the higher concentration of MUFA and PUFA in IC male belly fat when compared to MUFA and PUFA concentrations of physical castrate belly fat. What is interesting however, is the higher concentrations of total PUFA of IC males harvested in the early group (4 weeks post-second injection) led to higher iodine values (P < 0.05) than those of physical castrates harvested in the early group (Figure 4.2). However, there

were no differences (P > 0.05) in iodine values between IC males and physical castrates harvested in the late group (6 weeks post-second injection) (Figure 4.2). The magnitude of change in iodine value between pigs harvested in the early group versus those harvested in the late group for IC males was 1.9 iodine value units (Figure 4.3). The magnitude of change in iodine value between pigs harvested in the early group versus those harvested in the late group for physical castrates was only 0.5 iodine value units (Figure 4.3). This implies a greater opportunity to change fat quality IC males than with physical castrates using different dietary ingredients. The overall higher iodine values in this population of pigs, which contained 20% DDGS in the early finishing phase and 10% in the late finishing phase, are higher than those reported by Boler et al. (2011a), which did not contain DDGS in the finishing rations. This is not surprising as Stein and Shurson (2009) reported in a review that DDGS inclusion in finishing pig diets increased iodine value in 7 of 8 studies evaluated.

Cured Belly Characteristics

There were no significant interactions (P < 0.05) between sex and time of harvest post-second injection for any cured belly characteristics (Table 4.12) or between sex and ending live weight category except for pump uptake percentage (Table 4.13). Bellies from physical castrates categorized as heavy took up 3.24 percentage units less brine (P = 0.01) than bellies from IC males categorized as heavy. There were no differences in percentage brine uptake between physical castrates or IC males categorized as either light or median (Table 4.13). There were no differences in belly green weights (P = 0.24) or pumped weights (P = 0.65) between IC males (5.08 kg; 5.73 kg) and physical castrates (5.20 kg; 5.78 kg) when averaged over both harvest times (Table 4.12). Bellies from IC males (12.87%) took up a larger percentage of brine (P = 0.05) than bellies from physical castrates (11.32%), but physical castrates lost approximately

2.6% of pumped weight during equilibration while IC males lost 2.79% of pumped weight during equilibration. Thinner bellies (bellies from IC males) lost a higher ($P < 0.0001$) percentage of moisture (11.13%) in the smokehouse than thicker bellies (10.00%; bellies from physical castrates) (Table 4.12). This phenomenon is not new and was reported by Person et al. (2005), but they attributed the increase in cook loss percentage to thinner bellies also being lighter. Contrary to that study however, green weights in this study were similar. Even though cook loss percentage was greater in IC males when compared to physical castrates, cooked yields were not different ($P = 0.74$) between the two sexes when averaged over both harvest times (Table 4.12). Boler et al. (2011b) also reported no differences in cooked yields between IC males and physical castrates.

CONCLUSION

The use of the anti-GnRF immunological product (Improvest®) in this study had only minimal impacts on fresh pork quality with very few interactions among sex and time of harvest post-second interaction. No differences were detected for ultimate pH, tenderness, or color. Marbling was less in IC males than in physical castrates, but the magnitude of the difference was small. Lean cutting yields and carcass cutting yields of IC males were approximately 2.5 percentage units higher than physical castrates. The advantage in cutting yields were present in groups of pigs harvested either 4 or 6 weeks post second injection. Additionally, weight category did not affect cutting yield results. IC males had higher cutting yields regardless if they were classified as light, median, or heavy weight pigs. Advantages in cutting yields can be attributed to increases in shoulder, loin, and ham components as a percentage of chilled side weight. Fresh bellies of IC males were thinner and had narrower flop distances than physical castrates. IC males took up a higher percentage of brine than physical castrates, but lost a higher

percentage of brine during the curing and smoking process. This netted no cooked yield differences for cured bellies between IC males and physical castrates. Based on these data, cook cycles should be managed to optimize yields. Overall, immunological castration with Improvest® improved cutting yields, did not affect pork quality, made fresh bellies thinner, and did not affect cured belly characteristics when pigs were fed a moderate level of DDGS during the finishing phase of production.

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Table 4.1 Diet schedule and percent lysine inclusion by diet[1,2]

	Diet schedule		Lysine level, % of diet	
Time Period	Age of pigs (weeks)	Approximate wt (kg)	Physical castrate	Immunological castrate
Allotment[1]	1	2.27	N/A	N/A
Weaning[1]	3	5.80	N/A	N/A
Nursery	3	---	Same nursery diet provided to all treatments	
1st Grower period[1]	6	11.45	1.29	1.30
2nd Grower period[1]	9	24.15	1.21	1.30
Developer period[1]	12	40.80	1.13	1.13
1st Finish period (1st injection)[1]	15	63.55	1.04	1.10
2nd Finish period (2nd injection)[1]	19	94.60	0.83	1.00
Harvest (4 wk post second injection)[2]	23	124.54		
Harvest (6 wk post second injection)[2]	25	127.77		

[1]Approximate weight reflects means of all pigs in the population

[2]Approximate weight reflects only the 78 pigs in each group selected for indepth meat quality analysis

Table 4.2 The effect of GnRF immunological on carcass characteristics of pigs harvested either 4 or 6 weeks post-second injection

	Sex							
	Physical castrate		Immunological castrate			P - value		
Item	4 wk	6 wk	4 wk	6 wk	SEM	Sex	Time	Sex * Time
Live wt, kg	122.74	124.01	126.34	131.53	0.72	< 0.01	< 0.001	0.02
HCW, kg	91.36	92.60	91.03	94.00	0.51	0.57	< 0.01	0.19
Dressing, %	74.42	74.67	72.07	71.50	0.17	< 0.0001	0.57	0.16
Fat-O-Meater								
Loin depth, mm	63.0	62.6	60.8	61.2	0.49	0.09	0.97	0.68
Fat depth, mm	17.7	17.6	16.3	16.3	0.25	0.01	0.89	0.90
Estimated lean, %	55.63	55.66	56.22	56.27	0.16	0.09	0.90	0.97

Table 4.3 The effect of GnRF immunological on carcass characteristics of pigs classified as heavy, median, or light ending live weight

	Sex								
	Physical castrate			Immunological castrate				P - value	
Item	Light	Median	Heavy	Light	Median	Heavy	SEM	Weight	Sex * Weight
Live wt, kg	118.21	123.45	128.46	123.84	128.69	134.27	1.76	< 0.0001	0.85
HCW, kg	88.06	91.71	96.18	88.62	92.70	96.23	1.35	< 0.0001	0.56
Dressing, %	74.51	74.26	74.87	71.58	72.06	71.71	0.22	0.61	0.14
Fat-O-Meater									
Loin depth, mm	60.04	63.38	65.08	60.19	61.87	60.95	0.85	0.03	0.18
Fat depth, mm	17.27	16.73	18.88	15.27	16.63	16.94	0.46	0.02	0.19
Estimated lean, %	55.53	56.26	55.15	56.77	56.13	55.84	0.30	0.15	0.23

Table 4.4 The effect of GnRF immunological on carcass cut-out values of the shoulder and loin of pigs harvested either 4 or 6 weeks post-second injection

	Sex							
	Physical castrate		Immunological castrate			P - value		
Item	4 wk	6 wk	4 wk	6 wk	SEM	Sex	Time	Sex * Time
Whole shoulder, kg	9.57	9.82	9.87	10.36	0.06	< 0.01	< 0.01	0.25
% chilled side wt	21.72	22.05	22.64	22.87	0.08	< 0.01	0.08	0.76
Bone-in Boston, kg	3.89	3.84	4.14	4.29	0.04	< 0.0001	0.39	0.09
% chilled side wt	8.82	8.63	9.50	9.46	0.06	< 0.0001	0.32	0.51
Boneless Boston, kg	3.56	3.52	3.79	3.96	0.03	< 0.0001	0.21	0.05
% chilled side wt	8.08	7.91	8.69	8.75	0.06	< 0.0001	0.59	0.29
Bone-in picnic, kg	4.43	4.54	4.62	4.83	0.03	< 0.01	0.01	0.37
% chilled side wt	10.07	10.20	10.59	10.66	0.05	< 0.01	0.27	0.74
Boneless picnic, kg	3.51	3.53	3.65	3.74	0.03	0.02	0.28	0.51
% chilled side wt	7.97	7.93	8.38	8.26	0.05	0.02	0.31	0.67
Cushion, kg	0.81	0.80	0.84	0.85	0.01	0.07	0.82	0.61
% chilled side wt	1.84	1.80	1.93	1.88	0.02	0.09	0.26	0.87
Jowl, kg	1.24	1.30	1.08	1.13	0.02	0.01	0.12	0.91
% chilled side wt	2.81	2.91	2.47	2.49	0.04	< 0.01	0.44	0.57
Whole loin, kg	12.17	12.40	11.78	12.41	0.09	0.22	< 0.01	0.12
% chilled side wt	27.59	27.81	27.00	27.35	0.10	0.02	0.16	0.73
Trimmed loin, kg	9.95	10.15	10.01	10.55	0.07	0.07	< 0.01	0.15
% chilled side wt	22.58	22.77	22.96	23.27	0.09	0.07	0.19	0.76
Canadian back, kg	3.37	3.22	3.43	3.47	0.03	0.02	0.36	0.09
% chilled side wt	7.65	7.23	7.86	7.67	0.06	0.01	0.01	0.31
Tenderloin, kg	0.49	0.47	0.52	0.51	0.01	0.01	0.05	0.68
% chilled side wt	1.12	1.06	1.20	1.12	0.01	0.01	< 0.01	0.66
Sirloin, kg	0.81	0.80	0.83	0.87	0.01	0.03	0.42	0.18
% chilled side wt	1.84	1.80	1.90	1.91	0.02	0.04	0.60	0.42
Backribs, kg	0.66	0.70	0.69	0.70	0.01	0.37	0.09	0.34
% chilled side wt	1.50	1.58	1.58	1.55	0.02	0.40	0.50	0.09

Table 4.5 The effect of GnRF immunological on right side carcass cut-out values from the shoulder and loin of pigs classified as heavy, median, or light ending live weight

	Sex								
	Physical castrate			Immunological castrate				P - value	
Item	Light	Median	Heavy	Light	Median	Heavy	SEM	Weight	Sex * Weight
Whole shoulder, kg	9.31	9.74	10.02	9.72	10.14	10.48	0.15	< 0.0001	0.94
% chilled side wt	21.97	22.04	21.64	22.84	22.77	22.66	0.12	0.19	0.67
Bone-in Boston, kg	3.72	3.82	4.06	4.06	4.25	4.34	0.08	< 0.0001	0.46
% chilled side wt	8.77	8.66	8.74	9.54	9.54	9.37	0.10	0.80	0.67
Boneless Boston, kg	3.42	3.50	3.71	3.74	3.91	3.98	0.07	< 0.0001	0.48
% chilled side wt	8.06	7.94	7.99	8.79	8.77	8.59	0.09	0.60	0.66
Bone-in picnic, kg	4.33	4.56	4.58	4.58	4.69	4.90	0.07	< 0.0001	0.21
% chilled side wt	10.22	10.30	9.90	10.77	10.51	10.60	0.09	0.08	0.09
Boneless picnic, kg	3.38	3.58	3.60	3.60	3.66	3.84	0.06	< 0.0001	0.21
% chilled side wt	7.98	8.08	7.79	8.46	8.20	8.30	0.09	0.22	0.09
Cushion, kg	0.77	0.82	0.83	0.83	0.86	0.86	0.02	0.03	0.71
% chilled side wt	1.81	1.85	1.80	1.94	1.92	1.86	0.04	0.46	0.73
Jowl, kg	1.21	1.24	1.36	0.97	1.09	1.25	0.03	< 0.0001	0.29
% chilled side wt	2.85	2.81	2.93	2.31	2.43	2.70	0.07	0.02	0.25
Whole loin, kg	11.67	12.14	13.04	11.41	12.16	12.71	0.21	< 0.0001	0.34
% chilled side wt	27.51	27.45	28.14	26.78	27.28	27.46	0.16	0.01	0.36
Trimmed loin, kg	9.57	10.05	10.53	9.83	10.28	10.74	0.17	< 0.0001	0.97
% chilled side wt	22.59	22.71	22.72	23.08	23.06	23.22	0.17	0.82	0.93
Canadian back, kg	3.14	3.27	3.48	3.40	3.43	3.52	0.07	< 0.01	0.26
% chilled side wt	7.41	7.40	7.51	7.98	7.69	7.63	0.10	0.51	0.28
Tenderloin, kg	0.46	0.47	0.51	0.52	0.52	0.52	0.01	0.04	0.03
% chilled side wt	1.09	1.07	1.11	1.21	1.17	1.11	0.02	0.19	0.02
Sirloin, kg	0.76	0.83	0.83	0.81	0.84	0.89	0.02	< 0.01	0.51
% chilled side wt	1.80	1.86	1.79	1.90	1.88	1.93	0.03	0.89	0.34
Backribs, kg	0.64	0.67	0.74	0.67	0.72	0.70	0.02	< 0.01	0.04
% chilled side wt	1.52	1.51	1.59	1.57	1.61	1.51	0.03	0.97	0.06

Table 4.6 The effect of GnRF immunological on carcass cut-out values of the ham and belly of pigs harvested either 4 or 6 weeks post-second injection

	Sex							
	Physical castrate		Immunological castrate			P - value		
Item	4 wk	6 wk	4 wk	6 wk	SEM	Sex	Time	Sex * Time
Whole ham, kg	10.65	10.72	10.74	11.02	0.06	0.10	0.05	0.22
% chilled side wt	24.18	24.07	24.67	24.33	0.08	0.03	0.17	0.48
Trimmed ham, kg	9.19	9.19	9.57	9.72	0.06	< 0.01	0.41	0.44
% chilled side wt	20.87	20.65	21.97	21.43	0.10	< 0.01	0.03	0.36
Inside, kg	1.65	1.61	1.69	1.70	0.02	0.04	0.54	0.34
% chilled side wt	3.75	3.60	3.87	3.75	0.03	0.04	0.03	0.86
Outside, kg	2.18	2.17	2.24	2.30	0.02	0.01	0.51	0.27
% chilled side wt	4.95	4.87	5.16	5.08	0.03	0.01	0.22	0.97
Knuckle, kg	1.28	1.33	1.33	1.40	0.01	0.02	0.01	0.61
% chilled side wt	2.90	2.99	3.05	3.10	0.02	0.02	0.16	0.66
Light butt, kg	0.29	0.28	0.34	0.34	0.01	0.01	0.61	0.69
% chilled side wt	0.66	0.62	0.79	0.75	0.02	0.01	0.39	0.97
Shank meat, kg	0.67	0.65	0.72	0.72	0.01	0.01	0.65	0.74
% chilled side wt	1.52	1.47	1.65	1.59	0.02	0.01	0.16	0.82
Whole belly, kg	8.10	8.26	7.95	8.18	0.06	0.44	0.03	0.69
% chilled side wt	18.38	18.53	18.22	18.01	0.08	0.07	0.84	0.24
Belly, kg	5.17	5.35	5.09	5.19	0.05	0.23	0.07	0.65
% chilled side wt	11.75	11.99	11.66	11.43	0.07	0.04	0.97	0.13
Spareribs, kg	1.57	1.65	1.62	1.70	0.01	0.12	0.00	0.97
% chilled side wt	3.57	3.71	3.71	3.76	0.02	0.08	0.06	0.31

Table 4.7 The effect of GnRF immunological on right side carcass cut-out values from the ham and belly of pigs classified as heavy, median, or light ending live weight

	Sex								
	Physical castrate			Immunological castrate				P - value	
Item	Light	Median	Heavy	Light	Median	Heavy	SEM	Weight	Sex * Weight
Whole ham, kg	10.27	10.69	11.09	10.66	10.85	11.14	0.15	< 0.0001	0.21
% chilled side wt	24.26	24.19	23.93	25.04	24.35	24.11	0.14	0.01	0.19
Trimmed ham, kg	8.82	9.24	9.52	9.48	9.59	9.86	0.13	< 0.0001	0.18
% chilled side wt	20.84	20.91	20.54	22.29	21.54	21.27	0.16	0.01	0.10
Inside, kg	1.56	1.61	1.72	1.68	1.69	1.71	0.03	0.02	0.19
% chilled side wt	3.69	3.64	3.70	3.94	3.78	3.71	0.06	0.26	0.23
Outside, kg	2.04	2.18	2.31	2.25	2.24	2.33	0.04	< 0.0001	0.02
% chilled side wt	4.81	4.92	4.99	5.29	5.02	5.04	0.06	0.56	0.01
Knuckle, kg	1.25	1.31	1.35	1.34	1.35	1.41	0.02	< 0.01	0.75
% chilled side wt	2.96	2.96	2.92	3.13	3.03	3.05	0.04	0.47	0.65
Light butt, kg	0.29	0.27	0.30	0.38	0.34	0.31	0.02	0.29	0.16
% chilled side wt	0.67	0.61	0.64	0.88	0.76	0.67	0.04	0.03	0.17
Shank meat, kg	0.65	0.65	0.68	0.70	0.72	0.74	0.02	0.23	0.95
% chilled side wt	1.54	1.48	1.47	1.65	1.60	1.61	0.03	0.38	0.95
Whole belly, kg	7.78	8.17	8.59	7.59	8.08	8.52	0.14	< 0.0001	0.77
% chilled side wt	18.36	18.47	18.54	17.82	18.13	18.39	0.13	0.11	0.56
Belly, kg	5.04	5.20	5.54	4.81	5.15	5.46	0.10	< 0.0001	0.52
% chilled side wt	11.89	11.74	11.98	11.30	11.55	11.78	0.12	0.22	0.41
Spareribs, kg	1.57	1.61	1.65	1.63	1.66	1.69	0.03	0.06	0.91
% chilled side wt	3.72	3.63	3.57	3.84	3.71	3.65	0.04	0.02	0.94

Table 4.8 The effect of GnRF immunological on chilled right side weights and cutting yields of pigs harvested either 4 or 6 weeks post-second injection

	Sex							
	Physical castrate		Immunological castrate			P - value		
Item	4 wk	6 wk	4 wk	6 wk	SEM	Sex	Time	Sex * Time
Chilled side wt, kg	44.06	44.55	43.61	45.33	0.25	0.72	< 0.01	0.04
Lean cutting yield, %[1]	62.41	62.25	65.02	64.88	0.20	< 0.0001	0.66	0.99
Carcass cutting yield, %[2]	74.21	74.24	76.68	76.30	0.18	< 0.0001	0.56	0.49

[1]Lean cutting yield = ((trimmed ham + trimmed loin + Boston + picnic) / left chilled side wt)*100

[2]Carcass cutting yield = ((lean cutting yield components + trimmed belly) / left chilled side wt)*100

Table 4.9 The effect of GnRF immunological on chilled right side weights and cutting yields of pigs classified as heavy, median, or light ending live weight

	Sex								
	Physical castrate			Immunological castrate				P - value	
Item	Light	Median	Heavy	Light	Median	Heavy	SEM	Weight	Sex * Weight
Chilled side wt, kg	42.38	44.22	46.32	42.58	44.55	46.28	0.65	< 0.0001	0.70
Lean cutting yield, %[1]	62.52	62.57	61.90	65.68	64.65	64.52	0.32	0.11	0.43
Carcass cutting yield, %[2]	74.48	74.32	73.88	76.99	76.21	76.27	0.27	0.18	0.66

[1]Lean cutting yield = ((trimmed ham + trimmed loin + Boston + picnic) / left chilled side wt)*100

[2]Carcass cutting yield = ((lean cutting yield components + trimmed belly) / left chilled side wt)*100

Table 4.10 The effect of GnRf immunological on pork quality characteristics of pigs harvested either 4 or 6 weeks post-second injection

	Sex							
	Physical castrate		Immunological castrate			P - value		
Item	4 wk	6 wk	4 wk	6 wk	SEM	Sex	Time	Sex * Time
Shear force, kg	2.55	2.53	2.73	2.65	0.04	0.09	0.53	0.76
Cook loss, %	21.15	21.46	23.34	23.60	0.35	0.01	0.68	0.98
pH	5.58	5.54	5.57	5.57	0.01	0.57	0.45	0.22
Objective color[1]								
L*	46.04	48.24	47.59	46.79	0.24	0.93	0.20	0.01
a*	7.33	8.74	7.02	8.52	0.13	0.33	< 0.0001	0.83
b*	2.60	3.92	2.80	3.27	0.11	0.31	< 0.01	0.04
Subjective evaluations[2]								
Color	2.97	2.97	2.92	3.08	0.03	0.64	0.14	0.15
Marbling	2.55	2.36	2.41	2.01	0.06	0.04	0.01	0.32
Firmness	2.97	2.95	2.92	2.73	0.03	0.03	0.06	0.14
Loin composition								
Moisture, %	74.68	74.15	75.21	74.75	0.06	< 0.01	< 0.01	0.78
Fat, %	1.83	2.35	1.73	1.83	0.06	< 0.01	0.01	0.07
Drip loss, %	2.86	3.73	3.37	3.73	0.11	0.30	0.01	0.28

[1]L*, greater value indicates a lighter color; a*, greater value indicates a redder color; b*, greater value indicates a more yellow Color

[2]Subjective evaluations based on National Pork Producers Council standards

Table 4.11 The effect of GnRF immunological on pork quality characteristics of pigs classified as heavy, median, or light ending live weight

	Sex								
	Physical castrate			Immunological castrate				P - value	
Item	Light	Median	Heavy	Light	Median	Heavy	SEM	Weight	Sex * Weight
Shear force, kg	2.65	2.50	2.47	2.71	2.61	2.75	0.07	0.43	0.51
Cook loss, %	21.80	20.20	21.91	22.94	23.64	23.82	0.60	0.54	0.38
pH	5.53	5.59	5.55	5.55	5.55	5.61	0.01	0.08	0.02
Objective color[1]									
L*	48.12	46.83	46.48	47.42	48.12	46.03	0.41	0.90	< 0.01
a*	8.06	8.33	7.73	7.26	7.57	8.46	0.21	0.22	< 0.01
b*	3.09	3.32	3.37	3.20	2.84	3.06	0.18	0.85	0.46
Subjective evaluations[2]									
Color	2.96	3.04	2.92	3.04	2.92	3.04	0.05	0.94	0.17
Marbling	2.50	2.35	2.51	2.19	2.25	2.20	0.12	0.89	0.62
Firmness	2.96	2.96	2.96	2.88	2.75	2.83	0.05	0.62	0.62
Loin composition									
Moisture, %	74.56	74.41	74.28	75.02	75.03	74.89	0.10	0.30	0.76
Fat, %	1.99	1.97	2.30	1.64	1.92	1.78	0.13	0.28	0.25
Drip loss, %	3.32	3.16	3.40	3.55	3.66	3.43	0.18	0.99	0.62

[1]L*, greater value indicates a lighter color; a*, greater value indicates a redder color; b*, greater value indicates a more yellow Color

[2]Subjective evaluations based on National Pork Producers Council standards

Table 4.12 The effect of GnRf immunological on fresh and cured belly characteristics of pigs harvested either 4 or 6 weeks post-second injection

	Sex					P - value		
	Physical castrate		Immunological castrate					
Item	4 wk	6 wk	4 wk	6 wk	SEM	Sex	Time	Sex * Time
Fresh belly								
Length, cm	59.76	59.02	60.66	59.68	0.20	0.10	0.07	0.79
Width, cm	23.75	23.71	24.85	24.26	0.13	0.02	0.26	0.33
Thickness, cm[1]	3.31	3.50	3.29	3.15	0.03	0.01	0.72	0.01
Flop distance, cm	18.33	19.78	11.89	15.52	0.49	< 0.0001	0.01	0.22
Cured belly								
Green wt, kg	5.13	5.27	5.02	5.15	0.05	0.24	0.09	1.00
Pump wt, kg	5.65	5.91	5.65	5.81	0.05	0.65	0.01	0.54
Pump uptake, %	10.14	12.50	12.79	12.95	0.36	0.05	0.09	0.13
Equilibrium wt, kg	5.52	5.73	5.48	5.65	0.05	0.54	0.04	0.79
Cooked wt, kg	4.97	5.17	4.87	5.03	0.05	0.22	0.03	0.84
Cook loss, %[2]	10.12	9.88	11.34	10.92	0.10	< 0.0001	0.05	0.57
Cooked yield, %	96.84	98.11	97.03	97.67	0.18	0.74	0.02	0.40
Bacon slice composition								
Moisture, %	47.40	47.64	51.35	52.41	0.37	< 0.0001	0.32	0.53
Fat, %	37.27	37.30	31.57	30.76	0.48	< 0.0001	0.64	0.61

[1]Thickness is the average of 8 measurements collected on along the belly where, location 1 to 4 is from the anterior to posterior position of the dorsal edge of the belly; Location 5 to 8 is from the anterior to posterior position of the ventral edge of the belly

[2]Cook loss = ((equilibrium wt - cooked wt)/equilibrium wt)*100

Table 4.13 The effect of GnRF immunological on fresh and cured belly characteristics of pigs classified as heavy, median, or light ending live weight

	Sex								
	Physical castrate			Immunological castrate				P - value	
Item	Light	Median	Heavy	Light	Median	Heavy	SEM	Weight	Sex * Weight
Fresh belly									
Length, cm	58.97[a]	59.35[a]	59.85[a]	59.17[a]	60.09[a]	61.26[b]	0.37	< 0.01	0.32
Width, cm	23.72[a]	23.56[a]	23.92[a]	24.36[ab]	24.43[ab]	24.88[b]	0.23	0.34	0.85
Thickness, cm[1]	3.38b	3.42b	3.41b	3.19a	3.25b	3.22a	0.05	0.80	0.99
Flop distance, cm	18.39	19.65	19.14	15.02	11.91	14.18	0.75	0.11	0.65
Cured belly									
Green wt, kg	4.99	5.14	5.45	4.77	5.11	5.37	0.10	< 0.0001	0.53
Pump wt, kg	5.53	5.79	6.00	5.39	5.72	6.08	0.10	< 0.0001	0.46
Pump uptake, %	10.90	12.93	10.12	13.20	12.07	13.36	0.61	0.68	0.05
Equilibrium wt, kg	5.40	5.59	5.89	5.22	5.57	5.91	0.10	< 0.0001	0.44
Cooked wt, kg	4.86	5.03	5.31	4.62	4.95	5.28	0.10	< 0.0001	0.44
Cook loss, %[2]	10.20	10.00	9.81	11.51	11.09	10.79	0.16	0.02	0.70
Cooked yield, %	97.26	97.78	97.38	96.81	96.94	98.29	0.31	0.18	0.11
Bacon slice composition									
Moisture, %	48.32	47.90	46.32	53.29	51.03	51.32	0.57	0.04	0.41
Fat, %	36.25	36.76	38.83	29.33	32.12	32.04	0.73	0.03	0.45

[1]Thickness is the average of 8 measurements collected on along the belly where, location 1 to 4 is from the anterior to the posterior position of the dorsal edge of the belly; Location 5 to 8 is from the anterior to posterior position of the ventral edge of the belly

[2]Cook loss = ((equilibrium wt - cooked wt)/equilibrium wt)*100

Table 4.14 The effect of GnRF immunological on fatty acid profiles of fresh bellies from pigs harvested either 4 or 6 weeks post-second injection

	Sex							
	Physical castrate		Immunological castrate			P - value		
Item	4 wk	6 wk	4 wk	6 wk	SEM	Sex	Time	Sex * Time
Caproic (6:0), %	0.18	0.24	0.09	0.21	0.02	0.08	0.01	0.36
Capric (10:0), %	0.16	0.12	0.16	0.14	0.01	0.69	0.16	0.44
Lauric (12:0), %	0.14	0.15	0.14	0.13	0.01	0.65	0.68	0.58
Myristic (14:0), %	1.98	1.86	1.82	1.78	0.04	0.05	0.18	0.47
C14:1, %	0.03	0.04	0.02	0.01	0.01	0.09	0.59	0.52
Pentadecanoic (15:0), %	0.05	0.04	0.06	0.04	< 0.01	0.53	0.02	0.66
Palmitic (16:0), %	22.68	22.32	22.54	22.24	0.16	0.63	0.16	0.89
C16:1, %	3.36	3.43	3.19	3.41	0.14	0.66	0.47	0.70
Margaric (17:0), %	0.30	0.26	0.31	0.32	0.01	0.08	0.18	0.13
C17:1, %	0.36	0.34	0.35	0.30	0.01	0.13	0.01	0.40
Stearic (18:0), %	7.70	8.05	7.62	8.75	0.19	0.28	0.01	0.17
C18:1c	40.52	41.80	39.02	40.15	0.29	< 0.01	0.01	0.86
C18:2t	0.08	0.11	0.06	0.10	0.01	0.33	0.01	0.41
C18:2c	19.36	18.20	21.44	19.47	0.29	< 0.01	0.00	0.27
Linolenelaidic (18:3 n3), %	0.89	0.90	1.05	0.85	0.04	0.27	0.14	0.10
γ-Linolenic (18:3 n6), %	0.07	0.04	0.05	0.04	0.01	0.23	0.14	0.50
Arachidic (20:0), %	0.25	0.19	0.22	0.18	0.02	0.37	0.02	0.71
C20:1, %	0.62	0.55	0.58	0.60	0.02	0.84	0.38	0.14
C20:2, %	0.28	0.14	0.38	0.06	0.03	0.87	< 0.0001	0.04
C20:3 n3, %	0.05	0.08	0.04	0.07	0.01	0.28	0.03	0.89
C20:3 n6, %	0.46	0.72	0.36	0.73	0.03	0.37	< 0.0001	0.21
C20:4, %	0.43	0.38	0.45	0.41	0.01	0.27	0.02	0.86
Total SFA, %[1]	33.45	33.24	32.96	33.79	0.28	0.94	0.44	0.20
Total MUFA, %[2]	44.90	46.14	43.17	44.46	0.35	< 0.01	0.01	0.96
Total PUFA, %[3]	21.62	20.57	23.82	21.75	0.32	< 0.01	0.00	0.21
UFA:SFA ratio[4]	2.00	2.03	2.05	1.98	0.02	0.98	0.53	0.15
Iodine value[5]	77.69	77.22	79.88	77.97	0.42	0.03	0.06	0.24

Means within a row for experimental treatments without a common superscript differ (P < 0.05)

1Total SFA = (C6:0) + (C10:0) + (C12:0) + (C14:0) + (C15:0) + (C16:0) + (C17:0) + (C18:0) + (C20:0)

2Total MUFA = (C14:1) + (C16:1) + (C17:1) + (C18:1c) + (C20:1)

[3]Total PUFA = (C18:2t) + (C18:2c) + (C18:3 n3) + (C18:3 n6) + (C20:2) + (C20:3 n3) + (C20:3 n6) + (C20:4)

[4]UFA: SFA ratio = (total MUFA + total PUFA) / total SFA

[5]Iodine value = 16:1 (0.95) + 18:1 (0.86) + 18:2 (1.732) + 18:3 (2.616) + 20:1 (0.795) + 20:2 (1.57) + 20:3 (2.38) + 20:4 (3.19)

Table 4.15 The effect of GnRF immunological on fatty acid profiles of fresh bellies from pigs classified as heavy, median, or light ending live weight

	Sex								
	Physical castrate			Immunological castrate				P - value	
Item	Light	Median	Heavy	Light	Median	Heavy	SEM	Weight	Sex * Weight
Caproic (6:0), %	0.22	0.24	0.17	0.20	0.12	0.12	0.03	0.28	0.45
Capric (10:0), %	0.13	0.15	0.15	0.17	0.14	0.14	0.01	0.83	0.34
Lauric (12:0), %	0.13	0.16	0.15	0.12	0.13	0.17	0.01	0.08	0.32
Myristic (14:0), %	1.88	1.97	1.92	1.72	1.90	1.79	0.05	0.13	0.82
C14:1, %	0.03	0.05	0.02	0.01	0.01	0.02	0.01	0.59	0.33
Pentadecanoic (15:0), %	0.04	0.05	0.04	0.04	0.05	0.05	0.01	0.42	0.70
Palmitic (16:0), %	21.86	22.89	22.76	22.43	22.57	22.16	0.20	0.11	0.09
C16:1, %	3.51	3.28	3.38	2.93	3.17	3.80	0.20	0.21	0.11
Margaric (17:0), %	0.29	0.28	0.29	0.34	0.32	0.28	0.01	0.15	0.13
C17:1, %	0.37	0.31	0.37	0.33	0.33	0.32	0.01	0.26	0.12
Stearic (18:0), %	7.23	8.22	8.17	8.57	8.10	7.88	0.24	0.73	0.03
C18:1c	41.85	40.22	41.41	39.04	39.74	39.97	0.36	0.37	0.07
C18:2t	0.11	0.08	0.09	0.06	0.09	0.08	0.01	0.94	0.11
C18:2c	19.08	19.15	18.11	20.93	20.17	20.25	0.34	0.17	0.42
Linolenelaidic (18:3 n3), %	1.01	0.84	0.85	0.95	1.00	0.94	0.05	0.26	0.13
γ-Linolenic (18:3 n6), %	0.06	0.05	0.05	0.04	0.05	0.04	0.01	0.98	0.68
Arachidic (20:0), %	0.21	0.23	0.22	0.20	0.20	0.19	0.02	0.90	0.93
C20:1, %	0.62	0.51	0.62	0.55	0.64	0.57	0.02	0.92	0.01
C20:2, %	0.19	0.30	0.13	0.25	0.13	0.27	0.04	0.92	0.01
C20:3 n3, %	0.08	0.06	0.06	0.06	0.07	0.04	0.01	0.49	0.43
C20:3 n6, %	0.63	0.51	0.63	0.54	0.61	0.49	0.04	0.82	0.08
C20:4, %	0.43	0.39	0.39	0.43	0.42	0.43	0.02	0.38	0.69

Table 4.15 (cont.)

[1]Total SFA, %	31.99	34.18	33.87	33.81	33.52	32.78	0.34	0.14	0.01
[2]Total MUFA, %	46.37	44.38	45.80	42.86	43.91	44.67	0.41	0.14	0.02
[3]Total PUFA, %	21.60	21.38	20.31	23.27	22.53	22.54	0.37	0.12	0.55
[4]UFA:SFA ratio	2.14	1.94	1.96	1.97	2.00	2.07	0.03	0.10	< 0.01
[5]Iodine value	79.26	76.69	76.41	78.89	78.80	79.10	0.52	0.11	0.09

1Total SFA = (C6:0) + (C10:0) + (C12:0) + (C14:0) + (C15:0) + (C16:0) + (C17:0) + (C18:0) + (C20:0)

[2]Total MUFA = (C14:1) + (C16:1) + (C17:1) + (C18:1c) + (C20:1)

[3]Total PUFA = (C18:2t) + (C18:2c) + (C18:3 n3) + (C18:3 n6) + (C20:2) + (C20:3 n3) + (C20:3 n6) + (C20:4)

[4]UFA: SFA ratio = (total MUFA + total PUFA) / total SFA

[5]Iodine value = 16:1 (0.95) + 18:1 (0.86) + 18:2 (1.732) + 18:3 (2.616) + 20:1 (0.795) + 20:2 (1.57) + 20:3 (2.38) + 20:4 (3.19)

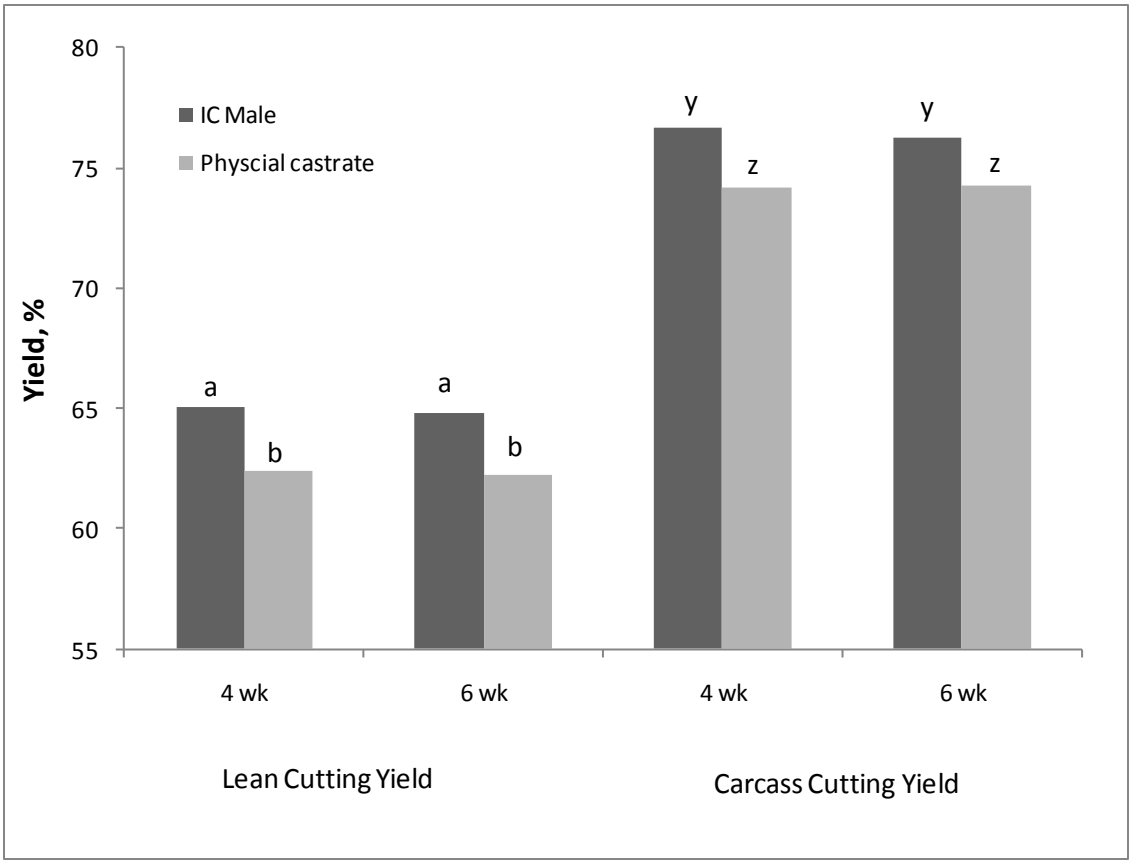

Figure 4.1 Effect of sex and time of harvest post-second injection on lean and carcass cutting yields. Means within a cutting yield parameter without a common superscript differ ($P < 0.05$) Lean cutting yield = ((trimmed ham + trimmed loin + bone-in Boston butt + bone-in picnic) / chilled side weight) * 100. Carcass cutting yield = ((lean cutting yield components + trimmed belly) / chilled side weight * 100.

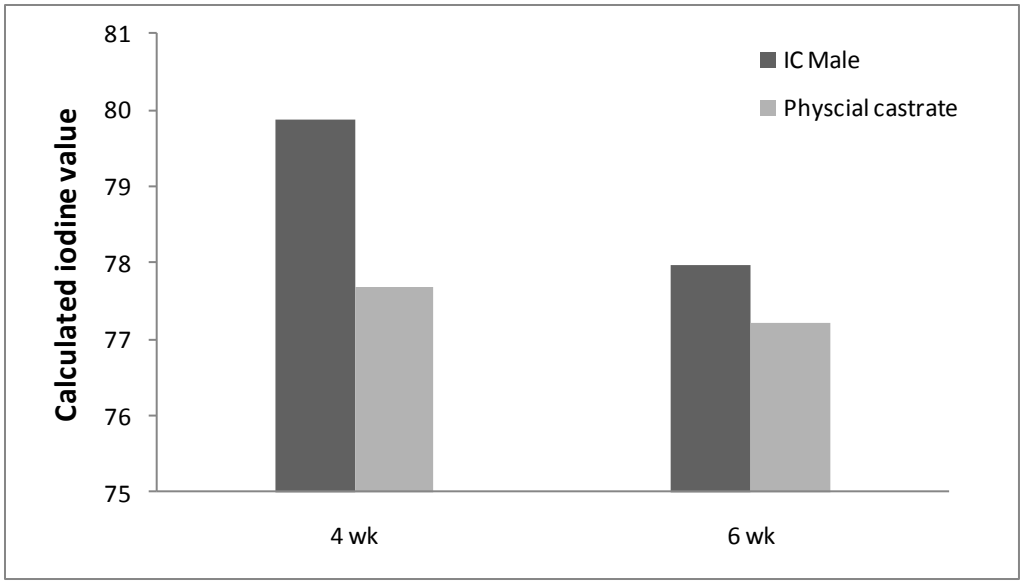

Figure 4.2 Effect of sex and time of harvest post second injection on calculated iodine value. Means without a common superscript differ ($P < 0.05$). Iodine values calculated with the following equation: IV = 16:1 (0.95) + 18:1 (0.86) + 18:2 (1.732) + 18:3 (2.616) + 20:1 (0.795) + 20:2 (1.57) + 20:3 (2.38) + 20:4 (3.19) + 20:5 (4.01) + 22:4 (2.93) + 22:5 (3.68) + 22:6 (4.64); Meadus et al., 2010.

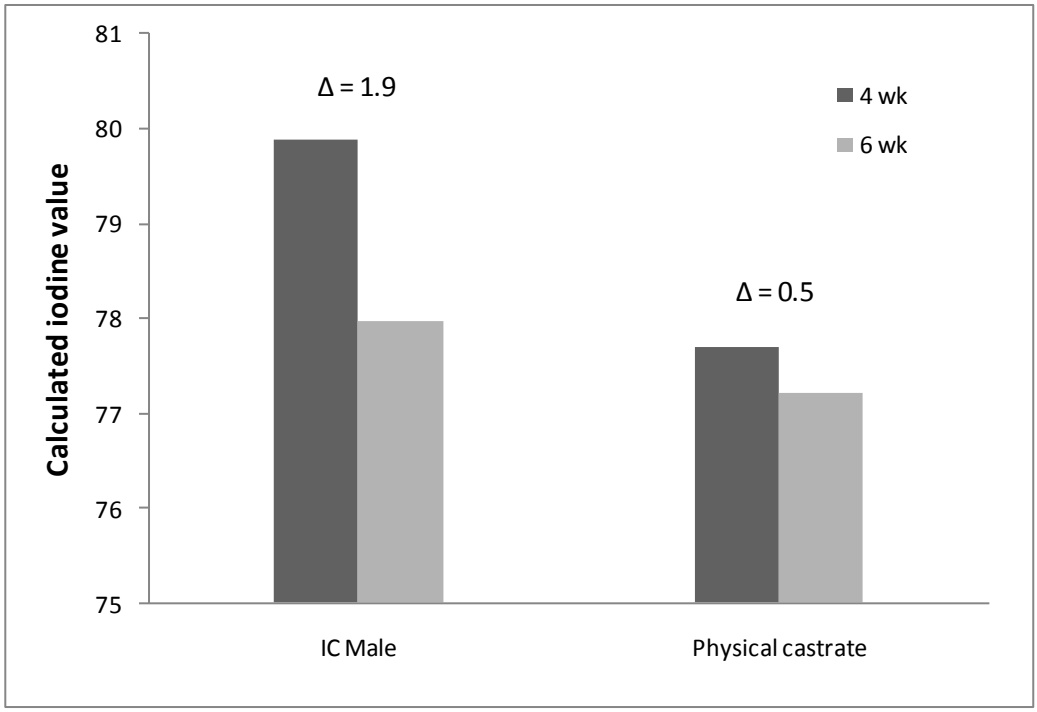

Figure 4.3 Change in calculated iodine value between harvest time post second injection of immunocastrated males and physical castrates. Iodine values calculated with the following equation: IV = 16:1 (0.95) + 18:1 (0.86) + 18:2 (1.732) + 18:3 (2.616) + 20:1 (0.795) + 20:2 (1.57) + 20:3 (2.38) + 20:4 (3.19) + 20:5 (4.01) + 22:4 (2.93) + 22:5 (3.68) + 22:6 (4.64); Meadus et al., 2010

AUTHOR'S BIOGRAPHY

Dustin Dee Boler was born in Bloomington, Indiana on June 23rd 1981. He was raised by his father Gerald Boler and grandmother Leona Carter on a small beef farm. Dustin was actively involved in 4-H and FFA throughout high school. He enjoyed exhibiting cattle and pigs at the local county fair. It was those experiences that led to perusing a degree in agriculture at Purdue University after graduating from Owen Valley High School in 1999. In 2004, Dustin completed a bachelor of science degree in both Animal Sciences and Agricultural Economics. Upon graduation, Dustin accepted a job with Tyson Prepared Foods in Dallas/Fort Worth, Texas. During his tenure at Tyson he completed a quality assurance supervisors training program and assumed a position as a quality assurance supervisor in a pepperoni manufacturing facility. After a year as a supervisor Dustin was promoted to the position of quality assurance superintendent in a joint USDA/FDA jurisdiction facility in Fort Worth. In the fall of 2006, Dustin began graduate school at the University of Illinois at Urbana-Champaign specializing in applied meat science under the guidance of Dr. John Killefer. During that time he also worked closely with Dr. Floyd McKeith. Dustin completed a master's of science degree in 2008 studying the effects of vitamin E on fresh pork color. His doctoral work focused on fresh and further processed product characteristics of intact male pigs castrated in a nonconventional manner. His research afforded him opportunities to speak at domestic and international conferences and meetings. In 2010, Dustin was awarded the David and Norraine Baker Graduate Fellowship in the department of animal sciences and was selected as a 2011 recipient of the ASAS Midwestern section animal science young scholar award.