

EFFECT OF IMMUNOLOGICAL CASTRATION ON COLOR STABILITY, SHELF LIFE
AND SENSORY CHARACTERISTICS OF FRESH AND FURTHER PROCESSED PORK

BY

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THESIS

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Abstract

Improvest[®] (Zoetis, Kalamazoo, MI) an immunological product for intact male pigs that stimulates the production of antibodies against gonadotropin-releasing factor (GnRF), temporarily blocking its activity and causing temporary castration. Use of Improvest delays castration, taking advantage of increased feed efficiency and lean gain of intact male pigs, without the negative sensory characteristics associated with boar taint. Fresh loin muscle quality has been extensively studied and immunological castration does not negatively affect loin muscle quality. However, more information is needed regarding the potential effects of immunological castration on other aspects of pork quality and in other products. To date, all data on loin muscle (LM) quality have been collected within a few days postmortem, but on average, pork loins and loin chops are stored for 7-14 days then display for 3-5 days prior to purchase causing discoloration. Thus, it is important to characterize and differences between immunologically castrated (IC) and physically castrated (PC) pigs with regard to color stability in pork chops. Furthermore, enhancement is a common practice in the meat industry to improve the sensory characteristics of fresh meat and it is important to characterize any potential differences between IC and PC pigs. Finally, most pork is consumed as further processed products. Thus, it is also important to characterize any effect immunological castration may have on the shelf life and sensory characteristics of pork sausage. Therefore, the objectives of these studies were to evaluate the effects of immunological castration on the color stability of fresh pork chops, the sensory characteristics and quality of enhanced pork chops, and the color stability, shelf life, and sensory characteristics of fresh sausage. To evaluate the effect of immunological castration of pigs on color changes during storage and the sensory characteristics of enhanced and non-enhanced loins, two studies were conducted. In study 1, chops from IC pigs, IC pigs fed ractopamine (IC+RAC), PC pigs, intact males, and gilts were evaluated for sensory

characteristics and instrumental tenderness (Warner-Bratzler Shear and star probe). In study 2, chops from IC pigs fed 0.55% and 0.65% SID lysine and PC pigs fed 0.55% SID lysine were displayed over 7 days and color changes were evaluated. After chops for color stability were removed, remaining loin sections were enhanced with a salt and phosphate solution and evaluated for sensory characteristics. In both studies, there were no differences between IC and PC pigs for sensory characteristics or instrumental tenderness of enhanced or non-enhanced loins. In study 2, there were also no differences in the discoloration of chops from IC and PC pigs. These data suggest immunological castration does not affect color stability of fresh pork chops or the quality of enhanced loins. To evaluate the effect of immunological castration of pigs on fresh sausage characteristics, sausage patties were evaluated for color stability, sensory characteristics, thiobarbituric acid relative substance (TBARS), textural properties and cooking loss over 3 storage times. In the first study, Boston butts (NAMP #407) from PC pigs fed 0.55% SID lysine and IC pigs fed 0.55% and 0.65% SID lysine were made into sausage patties. In a second study, sausage was formulated from IC and PC pigs targeting 25% fat. Overall, sausage discolored during display and lipid oxidation increased with increasing storage time. However, there were minimal differences between IC and PC treatments with regard to sensory or textural characteristics. Lipid oxidation did not differ between IC and PC pigs in study 1, but lipid oxidation was reduced overall in IC pigs compared with PC pigs in study 2. However, within each storage period, lipid oxidation did not differ between castration methods. Overall, immunological castration does not negatively affect the color stability, sensory characteristics, or quality of fresh pork sausage. Therefore, similar to previous studies using fresh loins, these data suggest that meat from IC pigs can be used similarly to meat from PC pigs as immunological castration is not detrimental to meat quality of fresh or enhanced loins or fresh sausage.

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Chapter 1:

Review of Literature

1.1. INTRODCUTION

With the world population expected to reach nine billion people by 2070 (Lutz, Sanderson, & Scherbov, 2001), new technologies are needed to increase the quantity and efficiency of lean meat production. However, consumers still demand high quality meat products that are the same or better than products currently on the market, regardless of efficiency.

Recently introduced to the market is Improvest[®] (Zoetis, Kalamazoo, MI) an immunological product for intact male pigs that stimulates the production of antibodies against gonadotropin-releasing factor (GnRF), temporarily blocking its activity causing temporary castration. Use of Improvest[®] delays castration, taking advantage of increased feed efficiency and lean gain of intact male pigs, without the negative sensory characteristics associated with boar taint. However, like any new technology used in the food industry, careful investigation of the quality and shelf life of meat produced from Improvest-managed pigs is needed to determine any potential differences that may limit the acceptance of that meat in the marketplace.

1.2. IMMUNOLOGICAL CASTRATION

Improvest[®] is an immunological product or vaccine used to control boar taint in intact males. The antigen used in Improvest is comprised of a synthetic incomplete analogue of natural gonadotropin releasing factor (GnRF) conjugated to a carrier protein. Improvest stimulates the pig's immune system to produce antibodies which block GnRF, the hypothalamic regulator of testicular function. Under normal circumstances, GnRF is released from the hypothalamus and binds to receptors in the pituitary which releases luteinizing hormone (LH) and follicle stimulating hormone (FSH). These hormones control the growth and activity of the testicles

leading to sexual maturity, behavioral changes, and boar taint in the intact male. Management of castration with Improvest requires 2 doses; the first injection is given after 9 weeks of age. This dose primes the immune system but does not stimulate effective levels of anti-GnRF antibodies to castrate, and thus the animal continues to function like an intact male. At least 4 weeks later, the animal is given a second dose, administered between 3-10 weeks prior to slaughter, which elicits high levels of specific anti-GnRF antibodies. These antibodies bind and neutralize endogenous GnRF, temporarily stopping the stimulation of the pituitary, and thus inhibiting testicular function. This allows androstenone and skatole (boar taint compounds) to be suppressed and eliminated from adipose tissue, effectively eliminating boar taint. (Hennessy, 2008)

Boar taint is an unpleasant odor and taste often associated with pork from sexually maturing intact males (Hennessy, 2008). Boar taint is caused by the production of androstenone and skatole (Bonneau, 1982). Androstenone is a steroid which is synthesized in the testes and secreted into circulation (Claus, Weiler, & Herzog, 1994). Androstenone accumulates in the fat, and its unpleasant aroma is detectable by approximately 35% of consumers (Malmfors & Lundström, 1983). Consumers, primarily women, can detect off odors associated with androstenone beginning at a threshold concentration between 0.2 and 1.0 $\mu\text{g/g}$ (Annor-Frempong, Nute, Whittington, & Wood, 1997). Fat from gilts and physical castrates contains $\leq 0.2 \mu\text{g/g}$ of androstenone (Prusa, Nederveld, Runnels, Li, King, & Crane, 2011) while fat from mature intact males usually contains concentrations greater than 0.5 $\mu\text{g/g}$ androstenone. Skatole originates from the microbial processing of tryptophan in the hindgut (Babol, Squires, & Lundström, 1999; Lösel, Lacorn, Büttner, & Claus, 2006). Most pigs have the ability to metabolize skatole through cytochrome (CYP2E1 and CYP2A) and aldehyde oxidase enzymes

in the liver (Diaz & Squires, 2000a, 2000b). Intact males are less efficient at eliminating skatole than gilts and barrows due to increased levels of testosterone, estrone sulfate, and androstenone (Zamaratskaia, Gilmore, Lundström, & Squires, 2007). These testicular steroids inhibit CYP2E1 enzyme activity (Zamaratskaia, Gilmore, Lundström, & Squires, 2007) causing skatole to accumulate in the fat (Babol, Squires, & Lundström, 1999) of intact males. Skatole aroma is detectable by consumers at concentrations greater than 0.2 µg/g (Annor-Frempong, Nute, Whittington, & Wood, 1997; Bonneau, Walstra, Claudi-Magnussen, Kempster, Tornberg, Fischer, et al., 2000). Fat from gilts and physical castrates usually contain ≤ 0.04 µg/g of skatole while intact males contain an average of 0.2 µg/g of skatole (Prusa, Nederveld, Runnels, Li, King, & Crane, 2011). In the US swine production system, boar taint is typically controlled through physical castration. Removal of the testicles eliminates the accumulation of these compounds. In a similar manner, immunological castration temporarily removes testicular function, thus, decreasing production of androstenone and allowing for more efficient elimination of skatole.

Though Improvest was developed to eliminate boar taint, its use also confers production benefits. Immunological castration delays castration allowing male pigs to grow as intact males for a longer portion of the production cycle. Intact males are more efficient and produce leaner carcasses than physical castrates (Xue, Dial, & Pettigrew, 1997). Thus, it is not surprising that immunological castrates (IC) are more efficient and have leaner carcasses when compared to physical castrates (PC). Several studies have concluded that IC pigs have a greater ADG in the finishing period (Pauly, Sproing, O'Doherty, Ampuero Kragten, & Bee, 2009; Morales, Cámara, Berrocoso, López, Mateos, & Serrano, 2011), reduced ADFI (Pauly, Sproing, O'Doherty, Ampuero Kragten, & Bee, 2009), improved feed conversion (Pauly, Sproing, O'Doherty,

Ampuero Kragten, & Bee, 2009), and increased carcass cutting yields (Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al., 2011; Boler, Killefer, Meeuwse, King, McKeith, & Dilger, 2012) when compared to PC pigs.

However, as stated above, new technologies such as immunological castration cannot gain widespread use if they negatively affect meat quality. To date, all studies would indicated that Improvest-managed pigs have fresh meat quality that is very similar to that of PC pigs. Immunologically castrated pigs have similar loin muscle (LM) ultimate pH (Pauly, Sproing, O'Doherty, Ampuero Kragten, & Bee, 2009; Boler, Killefer, Meeuwse, King, McKeith, & Dilger, 2012), Minolta L* (lightness) scores, subjective color scores, and drip loss when compared to PC pigs (Boler, Killefer, Meeuwse, King, McKeith, & Dilger, 2012). The effect of immunological castration on LM lipid content, however, is inconsistent. Morales, Cámara, Berrocoso, López, Mateos & Serrano (2011) and Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al. (2011) reported no differences in LM lipid content between IC and PC pigs while Boler, Killefer, Meeuwse, King, McKeith & Dilger (2012) found IC pigs have 0.3 percentage units less extractable lipid than PC pigs. Immunological castration is also not detrimental to sensory characteristics of fresh pork loins with no differences reported between pork chops of IC and PC pigs with regard to off odor or flavor (Font i Furnols, Gispert, Guerrero, Velarde, Tibau, Soler, et al., 2008), as well as, hardness, juiciness, or flavor (Font i Furnols, González, Gispert, Oliver, Hortós, Pérez, et al., 2009). Overall, immunological castration does not negatively affect the quality of fresh pork loins.

Although fresh LM quality has been extensively studied, more information is needed regarding the potential effects of immunological castration on other aspects of pork quality and in other products. To date, all data on LM quality have been collected within a few days post-

mortem, but on average, pork loins and loin chops are on display for several days prior to purchase. During this time, pork discolors. Defects in pork color are estimated to cost \$0.35/carcass (Cannon, Morgan, McKeith, Smith, Sonka, Heavner, et al., 1996) while discoloration causes a 5.4% average loss in sales for fresh meat (Williams, Frye, Frigg, Schefer, Scheller, & Liu, 1992). Thus, it is important to characterize potential differences between IC and PC pigs with regard to color stability in pork chops. Furthermore, enhancement is a common practice in the meat industry to improve the sensory characteristics of fresh meat. As such, it is also important to characterize any potential differences between IC and PC pigs with regard to enhanced meat quality. Finally, according to Pork Quick Facts ("Quick Facts: The pork industry at a glance," 2009), 19.8% of pork is consumed as sausage. Thus, it is also important to characterize any effect immunological castration may have on the shelf life and sensory characteristics of pork sausage.

1.3. LOIN QUALITY

1.3.1 Color

When asked about quality cues used to purchase meat, meat color and the amount of fat are the two quality cues and criteria mentioned most by consumers, with meat color being most important (Bredahl, Grunert, & Fertin, 1998). Discoloration deters consumers from purchasing meat as it is associated with increased lipid oxidation and undesirable sensory attributes such as off flavors and odors (Liu, Lanari, & Schaefer, 1995; Troy & Kerry, 2010). Williams, Frye, Frigg, Schefer, Scheller & Liu (1992) estimated the average loss of sales due to color deterioration was 3.7% for the entire meat department and 5.4% for fresh meat. Thus, the stability or maintenance of meat color is very important to both the packer and retailer. Although there are very few differences between IC and PC pigs with regard to LM color after harvest

(Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al., 2011; Boler, Killefer, Meeuwse, King, McKeith, & Dilger, 2012), color stability and formation of metmyoglobin (brown color) in meat from IC pigs, has not yet been determined.

Meat color is imparted by two proteins: hemoglobin, the pigment in blood, and myoglobin, the pigment in muscle. Myoglobin is the more important of the two with 80 to 90% of muscle color due to presence of myoglobin in well-bled muscle tissue. Myoglobin consists of a globular protein and heme ring. The color of meat is largely dependent on the oxidative state of iron within the heme ring (Aberle, Forrest, Gerrard, & Mills, 2001). When iron is in its reduced state (ferrous), deoxymyoglobin imparts the purple color of uncut meat. As cut meat is exposed to air, it becomes bright red or pink in color as iron in the heme ring reacts with oxygen (oxygenation) forming a stable pigment called oxymyoglobin. Over time, the iron portion of the heme ring becomes oxidized (ferric) causing the formation of metmyoglobin which is brown in color (Fox Jr, 1966). Through myoglobin reducing systems, metmyoglobin can be reduced to deoxymyoglobin until a point at which reduction capacity is exhausted. Loss of metmyoglobin reducing activity is due to many intrinsic (sex, breed, endogenous antioxidants, age, muscle type and metabolism, ultimate pH, and rate of pH decline) and extrinsic (temperature, O₂ availability, light exposure, packaging, and growth of microorganisms) factors (Giddings & Hultin, 1974; Bekhit & Faustman, 2005). When metmyoglobin can no longer be reduced back to deoxymyoglobin, meat will remain brown or “discolored” potentially limiting its consumer acceptance.

1.3.2. *Sensory Attributes*

Tenderness

Tenderness has become a high priority focus for the pork industry as overall acceptability of pork was more related to tenderness than to taste intensity, off flavor, or juiciness (Enfält, Lundström, Hansson, Lundeheim, & Nyström, 1997). Meat tenderness is a complex sensory characteristic which can be affected by production, grinding, value adding, and cooking methods used to prepare meat for consumption for the consumer (Thompson, 2002). In the pork industry, several post-mortem strategies such as electrical stimulation, processing (enhancement and further processing), and conditioning or aging of pork have been implemented to improve pork tenderness (Verbeke, Van Oeckel, Warnants, Viaene, & Boucqué, 1999).

Tenderness can be measured objectively through the use of Warner-Bratzler Shear (WBS) force (Boccard, Buchter, Casteels, Cosentino, Dransfield, Hood, et al., 1981) and star probe tenderness (Huff-Lonergan, Baas, Malek, Dekkers, Prusa, & Rothschild, 2002). Warner-Bratzler Shear force measures the amount of force it takes to break the muscle fibers; as force needed to break muscle fibers increases, tenderness decreases. The threshold level for pork to be considered tender is between 3.0-3.9 kg for WBS force (Van Oeckel, Warnants, & Boucqué, 1999). Warner-Bratzler shear force values were not different between IC and PC pigs when aged to 14 d post-mortem (Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al., 2011; Boler, Killefer, Meeuwse, King, McKeith, & Dilger, 2012). In both studies, IC and PC pigs had shear force values below 2.7 kg indicating tender pork.

Star probe force also measures tenderness but differs from WBS force in that the attachment used is not a dull blade but is in the shape of a five point star. The star shaped attachment compressing the meat is more representative of the mastication process and explains

more of the variation in subjective sensory tenderness (Caine, Aalhus, Best, Dugan, & Jeremiah, 2003). The amount of force required to puncture and compress the chop to 80% of the sample height is recorded (Huff-Lonergan, Baas, Malek, Dekkers, Prusa, & Rothschild, 2002). Star probe force values are slightly greater compared to WBS force values with values ranging from 4-6 kg (Prusa & Fedler, 2004). To date, star probe force of meat from IC pigs has not been reported

Juiciness and Flavor

Palatability, as it relates to meat, is determined by juiciness, tenderness, and flavor of meat products. Although tenderness is considered one of the major attributes of importance with regard to quality eating experiences, juiciness and flavor still play an important role in a quality eating experience. Juiciness may be influenced by a variety of factors such as intramuscular fat, ultimate pH, water holding capacity, concentration of glycogen, rearing conditions, and degree of doneness/cooking method (Aaslyng, Bejerholm, Ertbjerg, Bertram, & Andersen, 2003). However, Rincker, Killefer, Ellis, Brewer & McKeith (2008) indicated a low explanation of variation ($r^2 = 0.01-0.10$) between intramuscular fat and juiciness while Dransfield, Nute, Mottram, Rowan & Lawrence (1985) only explained 5% of the variation in juiciness with ultimate pH. Therefore, intramuscular fat and ultimate pH are not good predictors of juiciness. Degree of doneness and cooking method have the greatest influence on juiciness. For degree of doneness, as core temperature increases, juiciness is reduced, while meat cooked at a low oven temperature will give more juicy meat than meat cooked at a higher temperatures (Heymann, Hedrick, Karrasch, Eggeman, & Eilersieck, 1990). Pork species specific flavor is primarily influenced by genetics (sex and intramuscular fat in pork) and diet (Shahidi & Rubin, 1986). Variation explained by intramuscular fat for flavor were the strongest of all other sensory

characteristic but were still low ($r^2 = 0.13$). Off flavor was increased in intact males when compared to pork from all other sexes (Font i Furnols, Gispert, Guerrero, Velarde, Tibau, Soler, et al., 2008; Font i Furnols, González, Gispert, Oliver, Hortós, Pérez, et al., 2009). Given the low correlations of juiciness and flavor with other objective measures of pork quality (pH, marbling), there is no viable substitute for sensory panel data to measure these traits.

1.3.3 Enhancement

Enhancement of fresh pork is used to improve the quality and consistency of consumer eating experiences. During enhancement, fresh pork is injected with a salt and phosphate solution resulting in increased tenderness, juiciness, and flavor when compared with non-enhanced pork (Brewer, McKeith, Martin, Dallmier, & Meyer, 1991; Prestat, Jensen, McKeith, & Brewer, 2002; Hayes, Desmond, Troy, Buckley, & Mehra, 2006). These improvements result from increased water holding capacity and swelling of myofibrils in enhanced pork (Offer & Trinick, 1983). Enhanced pork, however, can also have increased off flavors when compared to non-enhanced pork due to the “soapy” flavor of sodium tripolyphosphate (Hayes, Desmond, Troy, Buckley, & Mehra, 2006). Nevertheless, enhancement is an important tool in the pork industry, it is important to characterize potential differences between pork loins from IC and PC pigs with regard to juiciness, tenderness, and off flavor.

1.4. SAUSAGE QUALITY

1.4.1 Color

Similar to fresh pork loins, fresh sausage also discolours during retail display. Although the mechanism of discoloration in sausage is similar to that of loins, there are other factors that may accelerate metmyoglobin formation. For example, both grinding and the addition of fat can

increase the formation of metmyoglobin. Grinding increases surface area increasing the amount of lean tissue exposed to oxygen, thus increasing the formation of oxymyoglobin and eventually metmyoglobin. Addition of fat, especially fat with increased proportions of poly-unsaturated fatty acids (PUFA), increases the risk of lipid oxidation. Polyunsaturated fatty acids are increased in intact male pigs (Boler, Clark, Baer, Meeuwse, King, McKeith, et al., 2011), therefore, it could be assumed that, in IC pigs, these fatty acids are enriched as well. Thus, it is possible that if fat in IC pigs is more unsaturated, it may be more prone to lipid oxidation. Lipid oxidation forms both primary products such as peroxides (Gray, 1978) and secondary products such as aldehydes, ketones, alcohols, hydrocarbons, esters, furans, and lactones (Frankel, 1984). Both the primary and secondary products of lipid oxidation can be oxidizing agents catalyzing metmyoglobin formation (Baron & Andersen, 2002).

The consideration of increased lipid oxidation is especially important with regard to IC pigs. Mackay, Pearce, Thevasagayam & Doran (2013) found the concentration of PUFA in IC pigs to be increased, more like intact males, than PC pigs. Because IC pigs have the potential to have a higher degree of PUFA, it is important to characterize any potential differences between IC and PC pigs with regard to color stability.

1.4.2 Sensory Characteristics

Texture and Mouthfeel

Texture, along with appearance and flavor, is one of the three main characteristics of food that guide consumer decisions regarding repeat purchases (Bourne, 2004). Texture and mouthfeel, as it relates to comminuted meat products, is most often attributed to binding properties. Binding properties are produced from extracting protein from meat to serve as a binder between meat pieces (Siegel & Schmidt, 1979). Fat also has a major influence on the

binding properties, tenderness, juiciness, mouthfeel, and overall appearance of emulsified meat products (Sofos & Allen, 1977; Hand, Hollingsworth, Calkins, & Mandigo, 1987). Bloukas & Paneras (1993) found sausage formulated with olive oil, relatively high PUFA content, was softer and had decreased overall palatability compared with sausage formulated with pork backfat. Due to IC pigs' potential to have an increased amount of PUFA, it is important to characterize any potential differences between IC and PC pigs with regard to texture and mouthfeel. Break strength and compression analysis (Bourne Analysis) are objective measures of the binding force between fat and meat particles (Herrero, Ordóñez, de Avila, Herranz, de la Hoz, & Cambero, 2007) and sensory characteristics of a food product (Bourne, Kenny, & Barnard, 1978) respectively. To date, these measures have not been reported in meat from IC pigs.

Off Flavor

Off flavor describes the development of flavors which are undesirable to the consumer. There are a variety of sources of off flavor development in meat with the primary contributing factors being genetic factors, diet, processing, bacterial growth, and lipid oxidation (Reineccius, 1979). With regard to immunological castration, there are two main concerns regarding off flavor. First, boar taint was a major concern during the primary development and introduction of Improvest; however, several studies have demonstrated that immunological castration effectively eliminates boar taint (Reid, Dufour, & Sirard, 1996; Font i Furnols, Gispert, Guerrero, Velarde, Tibau, Soler, et al., 2008; Font i Furnols, González, Gispert, Oliver, Hortós, Pérez, et al., 2009). Secondly, off flavors may develop secondary to lipid oxidation. Lipid oxidation consists of three stages: initiation, propagation, and termination. Lipid oxidation is initiated when labile hydrogen atoms are removed from double bonds on unsaturated fatty acids, resulting in the production of

free radicals. During propagation, free radicals interact with oxygen molecules to form peroxides, the primary products of oxidation, and fatty acyl hydroperoxides (Gray, 1978). Termination occurs when two free radicals combine to form a nonradical species. During accelerated oxidation, primary products are degraded into complex secondary products such as aldehydes, ketones, alcohols, hydrocarbons, esters, furans, and lactones (Frankel, 1984) that are responsible for rancid off flavors and odors often associated with lipid oxidation.

There are various assays used to measure lipid oxidation. Primary products of lipid oxidation can be measured by the peroxide value determination method which is used to quantify the amount of hydroperoxides in a product. However, the primary products of lipid oxidation are very unstable and readily change into secondary products and thus an assay which measures secondary products is most often used. Secondary products can be measured most commonly by the thiobarbituric acid reactive substances (TBARS) test (Tarladgis, Watts, Younathan, & Dugan, 1960).

The TBARS assay measures the pink chromophore that is formed by the reaction of 2-thiobarbituric acid (TBA) with secondary products from lipid oxidation of unsaturated fatty acids (Sørensen & Jørgensen, 1996). This method uses malondialdehyde as the calibration standard. Tarladgis, Watts, Younathan & Dugan (1960) set a threshold value of 0.5-1.0 µg of MDA/kg of meat as the point at which consumers find lipid oxidation in pork to be unfavorable.

Lipid oxidation can be accelerated in meat products by exposure to oxygen, grinding, light, and warm temperatures (Ladikos & Lougovois, 1990). Meat products with a higher degree of PUFA are also more susceptible to lipid oxidation (Rhee, Ziprin, Ordonez, & Bohac, 1988; Leskanich, Matthews, Warkup, Noble, & Hazzledine, 1997). Due to the potential increased in PUFA of IC pigs, it is important to investigate the possible differences between IC and PC pigs

with regard to the development of off flavors from lipid oxidation over time especially in ground products such as fresh sausage.

1.5. OBJECTIVES

It is expected that, given previous reports of similar LM quality between IC and PC pigs, immunological castration will not affect color stability of fresh pork chops, or quality and sensory characteristics of enhanced pork loins. However, immunological castration may alter the color stability and shelf life of fresh sausage due to increased concentration of PUFA documented in IC pigs. This increase in PUFA might lead to meat which is more susceptible to lipid oxidation, and in turn, discoloration and off flavor development.

Therefore, the objectives of these studies were to evaluate the following in meat from IC pigs:

- 1) Color of loin chops during display.
- 2) Sensory characteristics of enhanced loins.
- 3) Color stability, shelf life, and sensory characteristics of fresh pork sausage.

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Chapter 2:

Color stability and quality of fresh pork sausage from immunologically castrated pigs

2.1. ABSTRACT

To evaluate whether immunocastration of pigs affects fresh sausage characteristics, sausage patties were evaluated for color stability, sensory characteristics, thiobabaturic acid relative substance (TBARS), textural properties and cooking loss over 3 storage times. In the first study, Boston butts (NAMP #407) from physically castrated (PC) pigs fed 0.55% SID lysine and immunologically-castrated (IC) pigs fed 0.55% and 0.65% SID lysine were made into sausage patties. In a second study, sausage was formulated from IC and PC pigs targeting 25% fat. Overall, sausage discolored during display and lipid oxidation increased with increasing storage time. However, there were minimal differences between IC and PC treatments with regard to sensory of textural characteristics. Lipid oxidation did not differ between IC and PC pigs in study 1, but lipid oxidation was reduced overall in IC compared with PC pigs in study 2. However, within each storage period, lipid oxidation did not differ between sexes.

2.2. INTRODUCTION

Improvest® (Zoetis, Kalamazoo, MI) is an immunological product for intact males that stimulates the production of antibodies against gonadotropin-releasing factor (GnRF), blocking its activity and causing temporary castration. Improvest delays castration, taking advantage of increased feed efficiency and lean gain of intact male pigs (Dunshea, Colantoni, Howard, McCauley, Jackson, Long, et al., 2001; Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al., 2011), without the negative sensory characteristics associated with boar taint (Font i Furnols, Gispert, Guerrero, Velarde, Tibau, Soler, et al., 2008; Font i Furnols, González, Gispert, Oliver, Hortós, Pérez, et al., 2009). However, like any new technology used in the food industry, careful

investigation of the quality and shelf life of meat produced from Improvest-managed pigs is needed to determine any potential differences that may limit the acceptance of that meat in the marketplace.

According to the National Pork Board ("Quick Facts: The pork industry at a glance," 2009), 19.6% of pork is consumed as sausage products. Thus, the effect of immunological castration on the shelf life and sensory characteristics of pork sausage must be characterized. Immunologically castrated (IC) pigs grow as intact males until administered the second Improvest injection. This increased time spent as a boar might increase concentrations of polyunsaturated fatty acids (PUFA) in IC pigs, making them more similar to boars than physically castrated (PC) pigs (Mackay, Pearce, Thevasagayam, & Doran, 2013). Sausage with increased concentrations of PUFA is more susceptible to oxidative deterioration of lipids (Rhee, Ziprin, Ordonez, & Bohac, 1988; Leskanich, Matthews, Warkup, Noble, & Hazzledine, 1997) causing discoloration (Baron & Andersen, 2002) and rancid off flavors (Kanner, 1994). In emulsified products, increased PUFA causes products to be softer and less desirable (Bloukas & Paneras, 1993). Therefore, the potential increased PUFA in meat from IC pigs may be detrimental to sausage shelf life and palatability.

The objectives of the following studies are two-fold: (1) Evaluate color of sausage patties from immunologically castrated (IC) pigs compared to physically castrated (PC) pigs during display after frozen storage. (2) Evaluate lipid oxidation and sensory characteristics of fresh sausage patties from IC and PC pigs. Two studies were conducted to address two different scenarios regarding fat content of sausages. The first study formulated sausages from whole, boneless Boston Butts. Immunologically castrated pigs have leaner carcasses (Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al., 2011), therefore fat content of sausage in study 1 was

reduced in IC compared to PC. It is typical; however, that in addition to lean trim, additional fat trim is used in sausage manufacturing to produce sausages with consistent fat contents. Thus, study 2 used fat and lean trim from IC and PC pigs to formulate sausage with a targeted lipid content of 25%.

2.3. MATERIALS AND METHODS

Experimental procedures during the live phase of the following studies followed guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

2.3.1 Animal selection and raw material preparation study 1

Pigs used for this study were selected from a larger experiment, in which approximately 1000 pigs of commercial breeding comparable to those used in industry were allotted to treatment in a wean-to-finish building. Treatments from the larger study included PC pigs fed 0.55% Standard Ileal Digestible (SID) lysine and IC pigs fed 0.55% and 0.65% SID lysine for approximately 7 weeks prior to slaughter. Diets were formulated to meet exceed NRC requirements for physically castrated pigs. As such, PC pigs were fed 0.55% SID lysine and one treatment of IC pigs were fed similarly. However, to maximize growth of IC pigs, more lysine is required (Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al., 2011), therefore, one treatment of IC pigs included 0.65% SID lysine. These two lysine levels represent commercially applicable diets for PC and IC pigs. Physically castrated pigs were castrated within 7 days of birth. Immunologically castrated pigs received the first injection at ~4 months of age (16 weeks) and the second injection 4 weeks later at 20 weeks of age. Pigs were transported to a commercial facility and harvested under inspection at an approximate ending live weight of 120 kg (7 weeks after second Improvest injection). Carcasses from the 2 pigs closest to the pen mean weight (2 pigs per pen; 7 pens per

treatment group; n = 42) were shipped to University of Illinois Meat Science Laboratory for further analysis. Upon arrival, carcasses were fabricated according to specifications described by the National Association of Meat Purveyors (NAMP, 2007). Boston Butts (NAMP #407) were obtained to be used in this experiment. Boston butts were paired by pen (2 pigs/pen), ground and allotted into 4.5 kg batches. Pen served as the experimental unit for study 1.

2.3.2 Animal selection and raw material preparation study 2

Five IC pigs were transported to and slaughtered under inspection at the University of Illinois Meat Science Laboratory. Similar to study 1, IC pigs received the first injection of Improvest at ~4 months of age (16 weeks) and the second injection 4 weeks later at 20 weeks of age. All IC pigs were slaughtered at 27 weeks of age, 7 weeks after second injection. Five contemporary PC pigs from the same facility were slaughtered at the same time. Fat and lean trim were obtained from entire carcasses and pooled by castrate type.

Sub-samples of trim were collected for proximate analysis (method below). Based on these results, trim was mixed into five independent, 6.8 kg batches each treatment, targeting 25% lipid. For this study, batch served as the experimental unit. Batches were then treated similarly to study 1.

2.3.3 Sausage Preparation

To prepare fresh sausage patties, batches were mixed in a bowl chopper with salt, black pepper, and sugar (Table 1) and stuffed into 4x3x26 poly-bag casings. Sausages were crust frozen and cut into 1.25 cm thick patties using a band saw. From each experimental unit, 6 sausage patties were designated for display with 2 patties randomly assigned to each of 3 frozen storage times. Patties were placed on trays and packaged with PVC overwrap (oxygen

transmission rate = 11,627.9 cc/m²/day; moisture vapor transmission rate = 170.5 gm/m²/day) and assigned to 3 frozen storage times: 0 weeks, 4 weeks, or 12 weeks. Samples were held at -20°C for duration of assigned storage time. Two additional patties were stored in boxes and held at -20°C for analysis of break strength and compression analysis.

2.3.4 *Proximate Analysis*

For raw proximate analysis, a sub-sample of sausage was obtained prior to stuffing into casings. For cooked proximate analysis, the sausage patty used for break strength was obtained after analysis. For both raw and cooked proximate analysis, the sub sample was ground in a Cuisinart Food Processor (Model DLC 5-Tx, Cuisinart, Stamford, Ct), and a 10-g sample of homogenate was oven-dried at 110°C for approximately 24 h to determine percent moisture. The dried sample was then washed in an azeotropic mixture of warm chloroform:methanol (4:1) as described by Novakofski, Park, Bechtel & McKeith (1989) to determine extractable lipid.

2.3.5 *Evaluation of sausage patties in simulated retail display*

For both studies, upon conclusion of frozen storage, sausage patties were displayed in packages under constant lights (883 lx) at 4°C for 5 d. On days 1, 3, and 5, a trained, five-person panel evaluated patties for discoloration and overall color. Discoloration was evaluated using a 10 cm line scale (reference marks at 0.0, 2.5, 5.5, 7.5, and 10.0 cm), where every 1 cm represented 10% discoloration of both patties on the tray similar to methods described by Holmer, McKeith, Boler, Dilger, Eggert, Petry, et al. (2009). Panelists also evaluated chops for overall color using a 10 cm unstructured line scale where 0 represented a color score 1 (very pale), 5 represented a color score 3.5 (average), and 10 represented a color score 6 (very dark) according to NPPC color standards (NPPC, 1999). Values recorded were then converted to the NPPC 6 point color scale using the equation: $0.5 (\text{color score}) + 1$.

2.3.6 *Sensory characteristics of fresh sausage patties*

Upon conclusion of simulated retail display, sensory evaluation was conducted on one patty per tray using a trained panel composed of individuals from the University of Illinois Meat Science Laboratory. Panels consisted of six members who were trained according to the guidelines of the American Meat Science Association (AMSA, 1995). For study 1, six samples were evaluated per panel for 3 panels and the remaining three samples were evaluated in 1 additional panel providing a total of 4 panels. For study 2, six samples were evaluated in 1 panel, and four samples were evaluated in a second panel. Patties were allotted into panels such that each treatment was balanced in each panel. Panelists were separated by booths and evaluated the patties under red lighting. Water and unsalted crackers were provided between each sample. Panelists were instructed to remain consistent with either swallowing or expectorating samples. Patties were cooked in a 176°C oven for 14 minutes to reach a target internal temperature of 70°C. Panelists evaluated sausage patties for juiciness, mouth-feel, and off-flavor on a 15 cm unstructured line scale anchored at the center and both ends where 0 cm represented extremely crumbly, very dry, and no off flavor, and 15 cm represented extremely chewy/rubbery, very juicy, and intense off-flavor.

2.3.7 *Thiobarbituric Acid Relative Substances (TBARS)*

Upon conclusion of 5 day fresh storage, one patty per tray was homogenized in a Cusinart Food Processor (Model DLC 5-Tx, Cuisinart, Stamford, Ct) for TBARS analysis using a modified version of the procedure described by Leick and others (Leick, Puls, Ellis, Killefer, Carr, Scramlin, et al., 2010). After incubation, samples were placed in a 96-well plate and absorbance read at 530 nm in a plate reader (Synergy HT Multi-Mode Microplate Reader, Bio-Tek, Winooski, VT, U.S.A) to determine malonaldehyde (MDA) content. Samples were

compared to a standard curve (0-22.5 mg MDA/ml) and TBARS were expressed as $\mu\text{g MDA/kg}$ meat.

2.3.8 *Textural Analysis*

Upon conclusion of all frozen storage times, sausage patties, stored frozen for 12 weeks were cooked similarly to those for sensory panels and weighed before and after cooking to determine cook loss. Cook loss was expressed as a percentage of pre-cooked weight. After cooking, patties were allowed to cool at room temperature for one hour. Break strength (kg force) was determined using previously described methods by Bess and others (Bess, Boler, Tavárez, Johnson, McKeith, Killefer, et al., 2013).

An additional patty was cooked in a similar fashion and used to determine hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience according to the methods of Bourne, Kenny & Barnard (1978). Four 2.54 cm cores were collected from each sample and compressed on the Texture Analyzer TA.HD Plus (Texture Corp., Scarsdale, NY. Stable Microsystems, Godalming, UK.). A 5.08 cm diameter plate compressed each core into two consecutive cycles to 75 percent of the sample original height with 2 s intervals between cycles. The cross-head moved at a constant speed of 5 mm/s. A force-time curve was plotted and the peak force of the first compression was used to determine parameters previously mentioned. The values of the 4 cores were averaged and reported as hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience of each patty.

2.3.9 *Statistical Analysis*

For study 1, pen served as the experimental unit for all traits measured with 7 pens for each treatment. For study 2, batch served as experimental unit with 5 batches for each treatment. Data

were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Color during display, sensory and TBARS data were analyzed as repeated measures over time using an unstructured (UN) covariate matrix based upon goodness fit analysis using Akaike's information criterion to minimize variance. The statistical model for color during display included the fixed effects of treatment (PC pigs, IC pigs fed 0.55% lysine, and IC pigs fed 0.65% lysine), day of display, frozen storage time, and all interactions. The statistical model for sensory and TBARS included the fixed effects of treatment (PC pigs, IC pigs fed 0.55% lysine, and IC pigs fed 0.65% lysine), frozen storage time, and all interactions. Textural properties and proximate analysis were analyzed as a one way ANOVA with the fixed effect of treatment (PC pigs, IC pigs fed 0.55% lysine, and IC pigs fed 0.65% lysine). Assumptions of ANOVA were tested with Levene's test and Brown and Forsythe for homogeneity of variances. Normality of residuals was tested using the Univariate procedure of SAS. Means were separated using the PDIFF option employing a Tukey's adjustment for multiple comparisons. Differences were deemed significant at $P < 0.05$.

2.4. RESULTS AND DISCUSSION

2.4.1 Sausage Proximate Composition

For study 1, proximate composition (Table 1) of the sausage was affected by treatment. Sausage from PC pigs had the least moisture and the most fat ($P < 0.05$) while that from IC pigs fed 0.65% SID lysine had the most moisture and the least fat. Moisture and lipid of sausage from IC pigs fed 0.55% SID lysine was intermediate. For study 2, there were no differences ($P > 0.05$) between treatments for the fat or moisture content of raw sausage (Table 1) as sausage was formulated targeting a 25% lipid content. There were also no differences between treatments for the fat (20.6%) and moisture content (55.9%) of cooked sausage (Data not shown).

2.4.2 Sausage Color Stability

In both studies, the interaction of treatment (PC, IC) with day of display or frozen storage time was not significant ($P>0.05$) (Figure 1). The 3-way interaction of display time, storage time, and treatment was also not significant ($P>0.05$). However, there was an interaction between display day and frozen storage time ($P<0.01$) in both studies. As frozen storage time increased, the rate of discoloration during display increased as expected because metmyoglobin formation increases with storage time (Ledward & Macfarlane, 1971; Wanous, Olson, & Kraft, 1989) due to the oxidation of iron in the heme ring (Fox Jr, 1966). In study 1, when fat differences between IC and PC pigs was not controlled treatment did not alter discoloration ($P=0.68$). However in study 2, when all sausages were standardized to a similar fat level, discoloration was increased ($P=0.05$) marginally in sausages from PC pigs compared with IC pigs. Averaged across all storage periods and display times, discoloration unexpectedly increased ($P=0.04$) 1.1 percentage units in PC when compared with IC pigs. It was anticipated that due to potentially increased PUFA in IC pigs, sausage from IC pigs might exhibit increased discoloration subsequent to increased lipid oxidation (Faustman, Sun, Mancini, & Suman, 2010). This, however, was not the case. While PUFA were increased ($P<0.05$) in IC pigs slaughtered at 3-5 weeks after second injection compared to PC pigs (Mackay, Pearce, Thevasagayam, & Doran, 2013), at 6-8 weeks after second injection, PUFA content was similar between IC and PC pigs (Tavarez, Schroeder, McKeith, & Dilger, 2013). Therefore, it is possible that IC pigs slaughtered 7 weeks after second injection did not exhibit increased PUFA concentrations compared with PC pigs. Furthermore, increased discoloration of sausage from PC pigs by 1.1 percentage units, while statistically significant, is unlikely to alter consumer perceptions of discoloration.

In both studies, the interaction of treatment with day of display or frozen storage time was not significant for overall color ($P>0.05$) (Figure 2). The 3-way interaction between display time, frozen storage, and treatment was also not significant ($P>0.05$). In both studies, there was an interaction between display day and frozen storage time ($P<0.01$) as overall color changed differently with each day with each frozen storage time. In study 1, when fat differences between IC and PC pigs was not controlled, treatment ($P<0.01$) did affect overall color when averaged across all frozen storage points as PC pigs had the lightest color and IC barrows fed 0.55% lysine had the darkest. However, there were no differences between treatments ($P>0.05$) within each frozen storage point. In study 2, when all sausages were standardized to a similar fat level, sausage from IC pigs was darker ($P<0.01$) than sausage from PC pigs. However, the magnitude of differences was very small and within a range which consumers would consider normal colored. When consumers were asked to evaluate pale, soft, and exudative, normal, and dark, firm, and dry pork, they rated normal colored pork from 2.6 - 3.6 on a five point scale (Brewer, Lan, & McKeith, 1998). This would correspond to a 3.1 – 4.3 on the NPPC 6 point scale resulting in color ratings similar to our study.

2.4.3 Sausage Sensory Characteristics

For study 1, there was no interaction of treatment and frozen storage time for any sensory attribute measured ($P>0.05$) (Figure 3). There were also no effects of treatment noted for juiciness ($P= 0.83$), mouth-feel ($P=0.29$), or off flavor ($P=0.28$). However, as expected, there was an effect of frozen storage time ($P< 0.01$) on all sensory attributes. Sausage patties stored for 0 weeks were the driest while patties stored for 4 weeks were the juiciest. Sausage patties stored for 12 weeks were the most crumbly while sausage stored for 4 weeks was the most

rubbery. Finally, sausage stored for 0 weeks had the least off flavor while sausage stored for 12 weeks had the most off flavor.

For study 2, there was neither an interaction of treatment and frozen storage time ($P>0.05$) nor an effect of treatment on juiciness ($P= 0.22$) or mouthfeel ($P= 0.30$) (Figure 4). However, there was an interaction between treatment and frozen storage time for off flavor ($P< 0.01$). Off flavor did not differ between PC and IC pigs after 0 and 4 weeks of frozen storage, but after 12 weeks of frozen storage, off flavor was increased in sausage from PC pigs compared with that from IC pigs. There was also an effect of frozen storage time for mouthfeel ($P= 0.02$) and off flavor ($P< 0.01$). Similar to study 1, sausage stored for 4 weeks had the most rubbery mouthfeel while sausage stored for 12 weeks had the crumbliest. Furthermore, similar to study 1, sausage stored for 0 weeks had the least intense off flavor while sausage stored for 12 weeks had the most intense off flavor. However, in both studies, off flavor did not exceed 4.32 on a 15 cm scale indicating sausage from all treatments had minimal off flavor production, regardless of storage time.

2.4.4 Sausage TBARS

For both studies, there was no interaction between treatment and frozen storage time ($P>0.50$) (Figure 5). In study 1, when fat differences between IC and PC pigs was not controlled, lipid oxidation was not affected by treatment ($P=0.34$); however, in study 2, when all sausages were standardized to a similar fat level, lipid oxidation was increased ($P=0.05$) in sausage from PC pigs ($0.36 \mu\text{g MDA/kg}$ of meat) when compared to IC pigs ($0.47 \mu\text{g MDA/kg}$ of meat). Although this was not anticipated due to the potential increase of PUFA in IC pigs, at 6-8 weeks after second injection, PUFA content was similar between IC and PC pigs (Tavarez, Schroeder, McKeith, & Dilger, 2013). Therefore, it is possible that IC pigs slaughtered 7 weeks after second

injection did not exhibit increased PUFA concentrations compared with PC pigs, and thus lipid oxidation was not increased in IC pigs. Nevertheless, there were no differences in lipid oxidation between PC and IC pigs at each frozen storage point. In both studies, as frozen storage time increased ($P < 0.01$), lipid oxidation also increased. However, all TBARS levels for both studies were below the maximum detectable threshold level of 1.0 μg of MDA/ kg of meat for all weeks of frozen storage times (Tarladgis, Watts, Younathan, & Dugan, 1960). As indicated by off flavor scores as well, excessive lipid oxidation that would result in decreased consumer acceptance did not occur in any treatment in these studies.

2.4.5 Sausage Break Strength and Compression

For both study 1 and 2, break strength of sausage ($P > 0.05$) and textural properties did not differ between IC and PC pigs (Table 2 & 3). The lack of differences in the textural properties of IC and PC pigs could be due to the differences in fat level and PUFA concentration not being great enough to detect differences. Immunologically castrated and PC pigs were 7 weeks after second injection in both studies and only differed 7 percentage units of lipid content in study 1 and did not differ in study 2. While fat has a major influence on the binding properties, tenderness, juiciness, mouthfeel, and overall appearance of emulsified meat products (Sofos & Allen, 1977; Hand, Hollingsworth, Calkins, & Mandigo, 1987), it is possible that in this study the differences in fat level and PUFA concentrations were not great enough to detect differences.

2.5. CONCLUSION

With 19.6% of pork consumed as sausage ("Quick Facts: The pork industry at a glance," 2009), it is imperative to understand the effects a new technology such as immunological castration may have on the color stability, shelf life and sensory properties of fresh sausage. Results from both studies suggest that immunological castration does not affect color stability of

fresh sausage. Immunological castration also did not negatively affect the lipid oxidation or sensory characteristics of fresh sausage in either study. Therefore, pork from immunologically castrated pigs can be used similarly to that of physically castrated pigs without detrimental effects on the quality of fresh pork sausage.

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2.7. FIGURES AND TABLES

Figure 1: Color stability as reflected by percent discoloration of fresh pork sausage from immunologically castrated (IC) and physically castrated (PC) pigs. Panel A: Treatments included IC pigs fed 0.55% SID lysine and 0.65% SID lysine and PC pigs fed 0.55% SID lysine. Sausages were not standardized to a similar fat content. Effects of treatment and interactions of treatment with length of frozen storage, retail display or both were not significant ($P \geq 0.22$). Panel B: Treatments included IC and PC pigs with sausages standardized to a similar fat content. Interactions of treatment with length of frozen storage, retail display or both were not significant ($P \geq 0.09$).

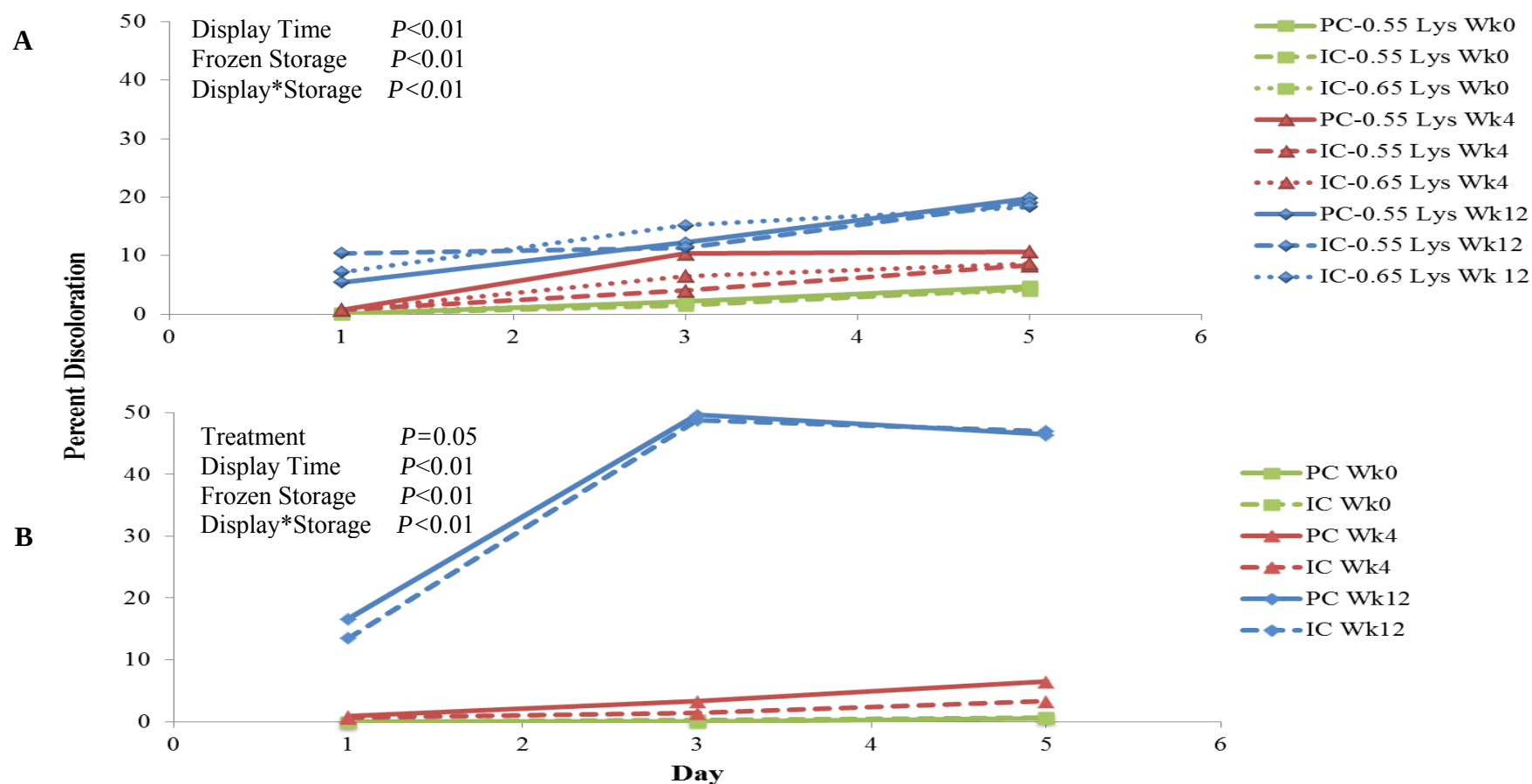


Figure 2: Color stability as reflected by overall color of fresh pork sausage from immunologically castrated (IC) and physically castrated (PC) pigs. Panel A: Treatments included IC pigs fed 0.55% SID lysine and 0.65% SID lysine and PC pigs fed 0.55% SID lysine. Sausages were not standardized to a similar fat content. Effects of display time and interactions of treatment with length of frozen storage, retail display or both were not significant ($P \geq 0.42$). Panel B: Treatments included IC and PC pigs with sausages standardized to a similar fat content. Effects of display time and interactions of treatment with length of frozen storage, retail display or both were not significant ($P \geq 0.14$).

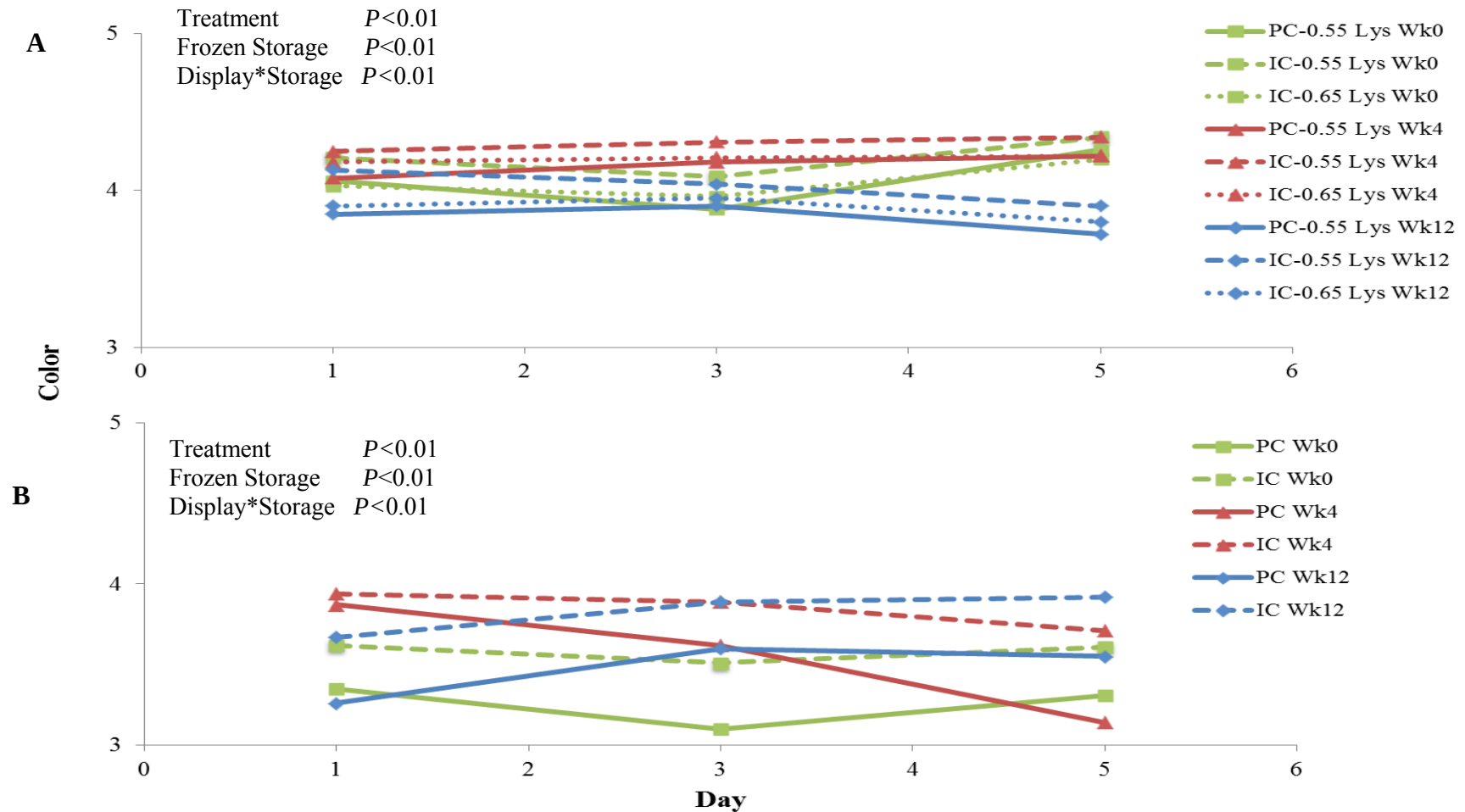


Figure 3: Effect of immunological castration on the sensory characteristics of pork sausage from immunologically castrated (IC) and physically castrated (PC) pigs. Treatments included IC pigs fed 0.55% SID lysine and 0.65% SID lysine and PC pigs fed 0.55% SID lysine. Sausages were not standardized to a similar fat content.

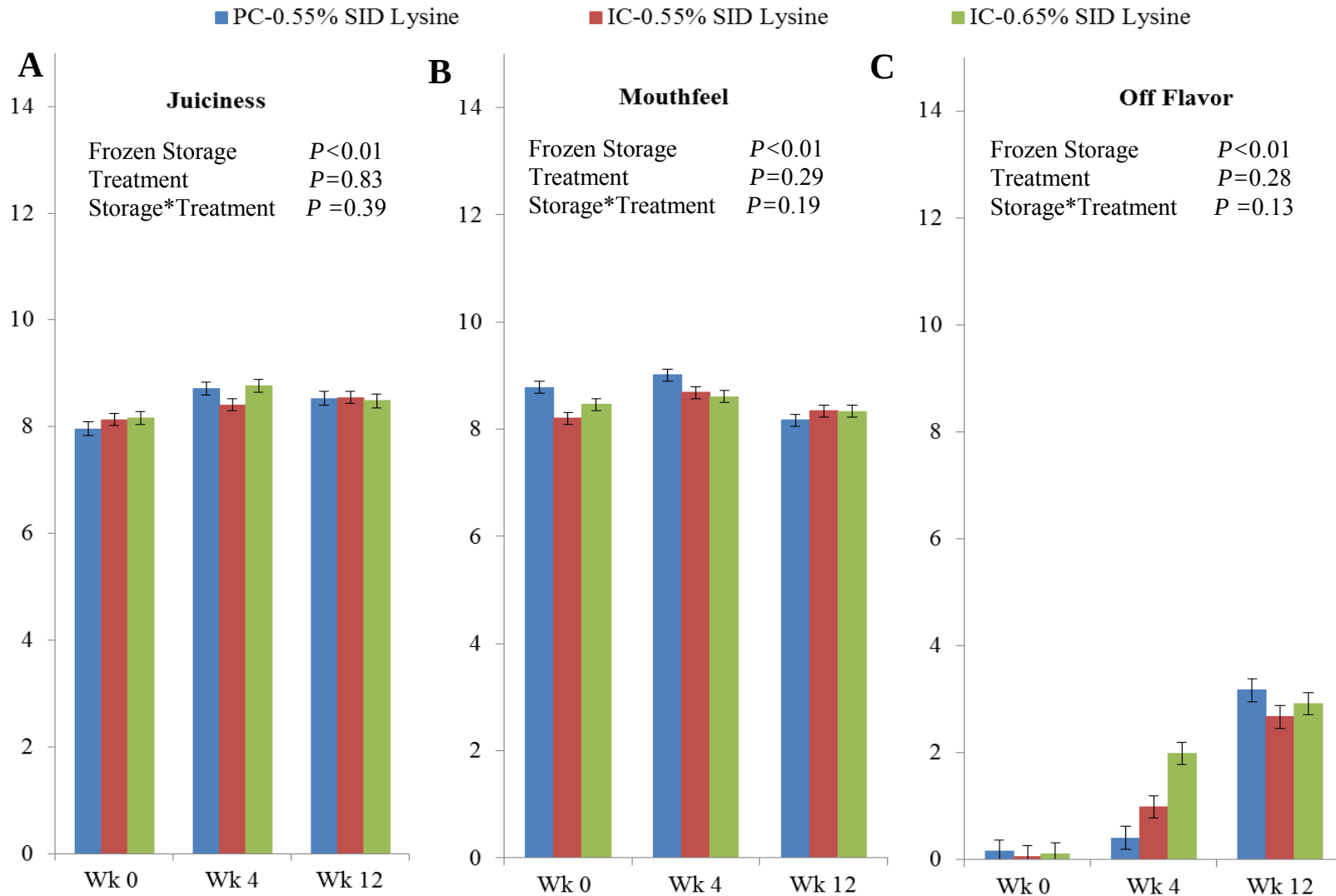


Figure 4: Effect of immunological castration on the sensory characteristics of pork sausage standardized to a similar fat content from immunologically castrated (IC) and physically castrated (PC) pigs

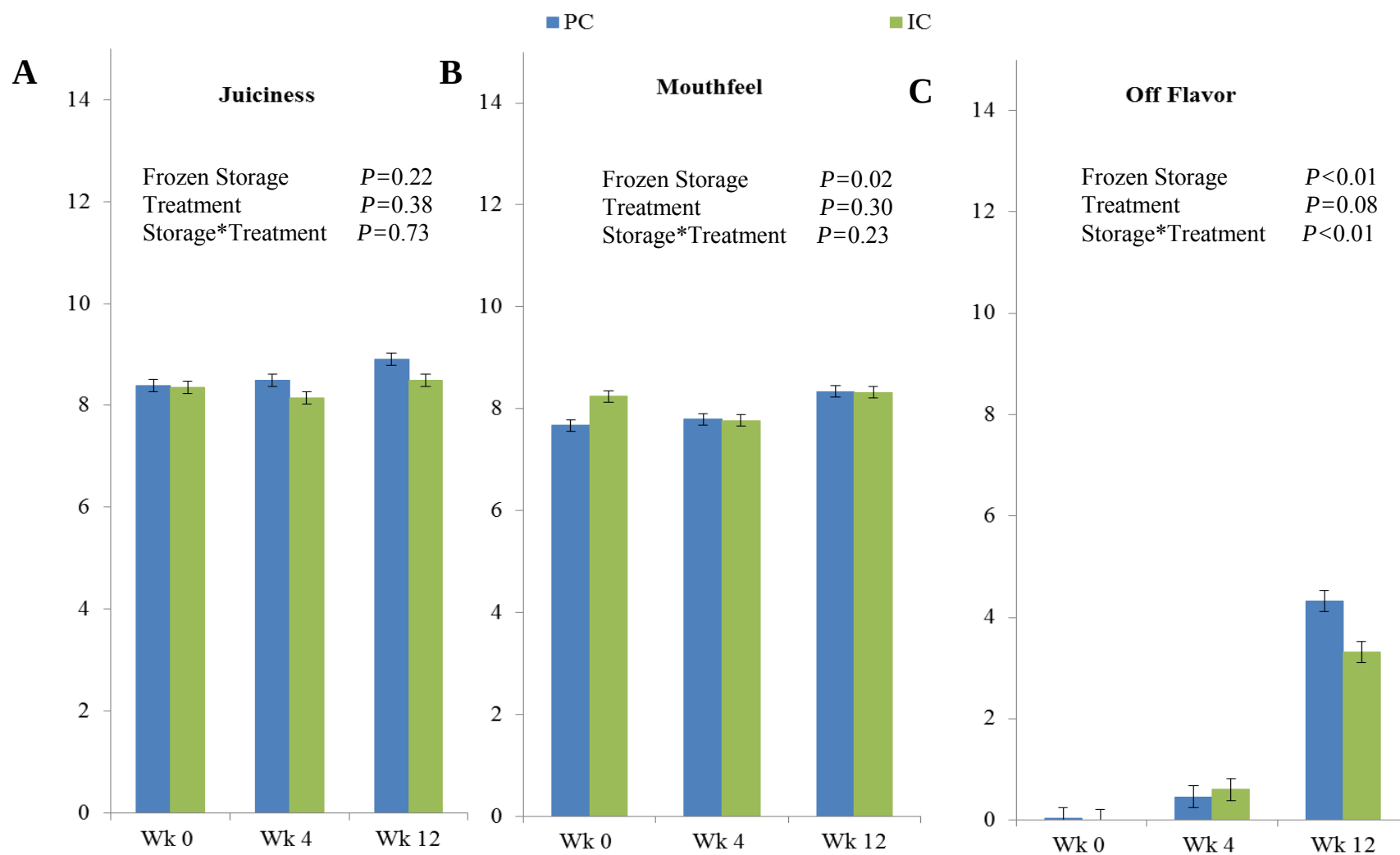


Figure 5: Effect of immunological castration on TBARS from immunologically castrated (IC) and physically castrated (PC) pigs. Panel A: Treatments included IC pigs fed 0.55% SID lysine and 0.65% SID lysine and PC pigs fed 0.55% SID lysine. Sausages were not standardized to a similar fat content. Effects of treatment and interaction of treatment with length of frozen storage were not significant ($P \geq 0.53$). Panel B: Treatments included IC and PC pigs with sausages standardized to a similar fat content. Interaction of treatment with length of frozen storage was not significant ($P \geq 0.67$).

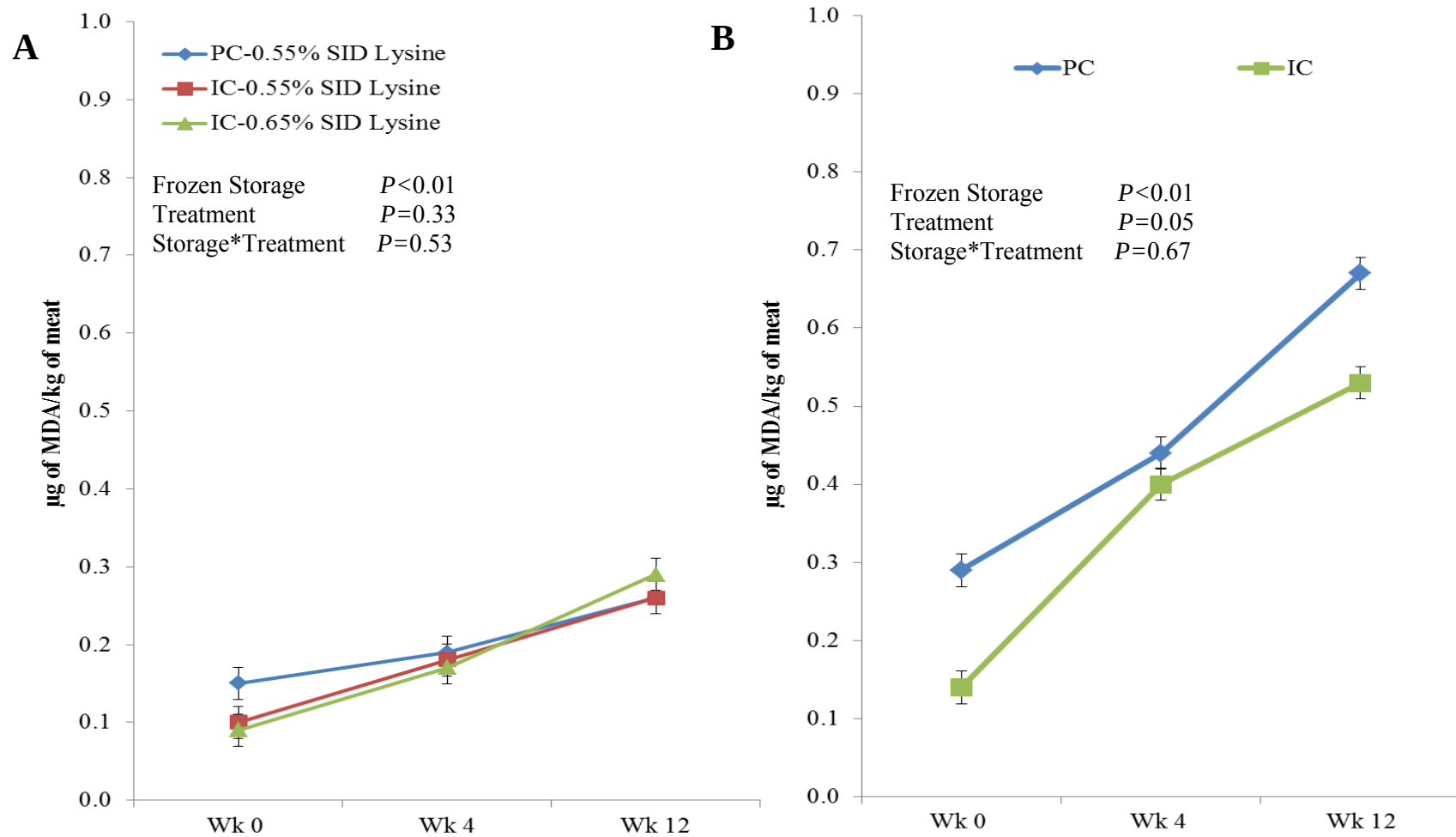


Table 1. Ingredients and proximate composition of sausage from immunologically castrated (IC) and physically castrated (PC) pigs

	Study 1			Study 2	
	PC	IC-0.55%	IC-0.65%	PC	IC
Salt, g/kg	5.8	5.8	5.8	5.8	5.8
Dextrose, g/kg	3.1	3.1	3.1	3.1	3.1
Black Pepper, g/kg	1.4	1.4	1.4	1.4	1.4
Moisture, %	62.71 ^a	65.96 ^{ab}	68.28 ^b	58.30	57.60
Lipid, %	21.66 ^a	17.13 ^{ab}	14.43 ^b	24.60	25.20

^{a,b} Per study, means within a row lacking a common superscript differ (P<0.05)
0.55% and 0.65% designate level of standard ileal digestible lysine

Table 2. Textural properties of cooked fresh sausage from physical castrates (PC) and immunological castrates (IC) fed 0.55% and 0.65% standard ileal digestible (SID) lysine

Item	PC	IC-0.55	IC-0.65	SEM	P-Value
Break Strength, kg	4.87	6.50	6.10	0.82	0.49
Hardness, kg	13.34	12.94	15.05	8.01	0.16
Fracturability, kg	12.11	12.14	14.48	12.14	0.31
Adhesivness	-0.01	-0.01	-0.01	0.002	0.73
Springiness	0.62	0.66	0.69	0.03	0.34
Cohesivness	0.28	0.28	0.28	0.01	0.99
Gumminess, kg	3.51	3.71	4.61	4.24	0.18
Chewiness, kg	2.34	2.46	2.83	2.68	0.40
Resilience	0.08	0.80	0.82	0.00	0.89

Table 3. Textural properties of cooked fresh sausage from physical castrates and immunological castrates

Item	PC	IC	SEM	P-Value
Break Strength, kg	5.397	4.989	0.320	0.39
Hardness, kg	18.38	20.17	14.04	0.40
Fracturability, kg	18.38	20.17	14.04	0.40
Adhesivness	-0.01	-0.03	0.01	0.19
Springiness	0.603	0.617	0.019	0.62
Cohesivness	0.256	0.266	0.007	0.33
Gumminess, kg	4.71	5.44	5.14	0.35
Chewiness, kg	2.86	3.41	3.99	0.35
Resilience	0.063	0.066	0.001	0.09

Chapter 3

Color stability and sensory characteristics of fresh and enhanced pork loins from immunologically castrated pigs

3.1. ABSTRACT

To evaluate whether immunocastration of pigs affects loin color changes during storage and enhanced quality, chops were evaluated for color stability and sensory characteristics. In study 1, chops from immunologically castrated (IC) pigs, IC pigs fed ractopamine (IC+RAC), physically castrated (PC) pigs, intact males, and gilts were evaluated for sensory characteristics. In study 2, chops from IC pigs fed 0.55% or 0.65% SID lysine and PC pigs fed 0.55% SID lysine were displayed for 7 days; color was evaluated. Remaining loin sections were enhanced with salt and phosphate and evaluated for sensory characteristics. In both studies, there were no differences between IC and PC pigs for sensory characteristics in enhanced or non-enhanced loins. In study 2, there were no differences between IC and PC pigs for loin chop discoloration. Overall, immunological castration does not negatively affect the color stability or enhanced quality of pork loins.

3.2. INTRODUCTION

With rising feed costs and an increased demand for meat, technologies that improve feed efficiency and meat yield without compromising quality are becoming increasingly important. One such technology, Improvest® (Zoetis, Kalamazoo, MI), is an immunological product for intact males that stimulates the production of antibodies against gonadotropin-releasing factor (GnRF), temporarily blocking its activity and causing castration. Fresh, non-enhanced pork from young, light weight immunologically castrated (IC) pigs had the same sensory characteristics as physically castrated (PC) pigs (Font i Furnols, Gispert, Guerrero, Velarde, Tibau, Soler, et al.,

2008; Font i Furnols, González, Gispert, Oliver, Hortós, Pérez, et al., 2009). However, in the United States, pork not only comes from older, heavier weight pigs compared to those used in Europe, but pork is also often enhanced with salt and phosphate solutions to provide more consistent eating experiences for consumers. Thus, potential differences between IC and PC pigs in addition to determining the quality of pork loins from US industry typical pigs, enhanced loin quality should also be characterized.

Quality is a general term encompassing many aspects of the appearance and palatability of meat. Meat color is one of the two quality cues mentioned most by consumers when asked about the criteria they use to purchase meat (Bredahl, Grunert, & Fertin, 1998). Discoloration often deters consumers from purchasing products as it indicates meat may exhibit increased lipid oxidation and undesirable sensory attributes such as off-flavors and odors (Liu, Lanari, & Schaefer, 1995; Troy & Kerry, 2010). Williams, Frye, Frigg, Schefer, Scheller & Liu (1992) estimated the average loss of sales due to color deterioration was 3.7% for the entire meat department and 5.4% for fresh meat. Thus, the stability or maintenance of meat color is very important to both the packer and retailer. New technologies, such as immunological castration, cannot have negative effects on color stability and still have a place in the market.

Palatability is comprised of tenderness, juiciness, and flavor. Tenderness is a main focus for the pork industry as overall acceptability of pork was more related to tenderness than to taste intensity, off flavor, or juiciness (Enfält, Lundström, Hansson, Lundeheim, & Nyström, 1997). Meat tenderness is a complex sensory characteristic which can be affected by production, grinding, value adding, and cooking methods used to prepare meat for consumption for the consumer (Thompson, 2002). Boar taint (androstenone and skatole) is another priority for the US pork industry as approximately 35% of consumers find it offensive. In the US, boar taint is

typically controlled through physical castration as removal of the testicles eliminates the risk of boar taint. Immunological castration works similarly to physical castration as testicular function is decreased lowering the risk of boar aroma. Although immunological castration does not affect the sensory characteristics of pork from young, lightweight pigs, pigs typical to the US production system has not been investigated.

Thus, the objectives of the following studies were two-fold: (1) Evaluate the sensory characteristics of enhanced and non-enhanced loins from IC and PC pigs. (2) Evaluate the color of loin chops during display from immunologically castrated (IC) pigs compared to physically castrated (PC) pigs. Our hypothesis was that immunological castration would have no detrimental effect on the color during storage of fresh pork chops or sensory attributes of enhanced and non-enhanced pork chops.

3.3. MATERIALS AND METHODS

Experimental procedures during the live phase of both experiments followed guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

Study 1

Sensory characteristics and instrumental tenderness of fresh pork from immunologically castrated pigs

3.3.1 Animal Selection

Ninety-six pigs (Génétiporc G-Performer boars crossed with Fertilis 25 sows; (Génétiporc, Alexandria, MN) in two separate blocks (192 total) were housed at the University of Illinois Swine Research Center. Farrowing group was considered as a block and there were two weeks

between blocks. The experiment included PC pigs, intact males, IC pigs, IC pigs fed ractopamine hydrochloride (RAC; Paylean, Elanco Animal Health, a division of Eli Lilly and Co., Greenfield, IN) and gilts. Physically castrated pigs were castrated within 7 days of birth, while IC pigs received the first injection at 16 weeks of age and the second injection at 20 weeks of age. There were 5 replications per block for IC pigs, PC pigs, intact males, and gilts. Four replications of IC pigs per block (n=16) were fed ractopamine hydrochloride (IC+RAC). These IC pigs designated for RAC treatment were switched to an experimental diet that included 5 mg/kg ractopamine hydrochloride 7 days after they received the second injection of Improvest (approximately 17 weeks of age).

All pigs were individually weighed every two weeks prior to the second injection and then each week after receiving the second injection. At 28 d after second injection, pigs were weighed to determine potential final farm weight. Any pen with an average pig body weight heavier than 130 kg was selected for harvest, weighed at 32 d after second injection, tattooed, and transported to the University of Illinois Meat Science Laboratory. The initial group of pigs was harvested 33 d after second injection. The selection process was repeated and pigs were harvested at 40 or 47 d after second injection as they reached an average body weight of 130 kg. Thus, all pigs on the study were harvested over a 3 week period within their respective block.

3.3.2 Warner-Bratzler Shear Force

Carcasses were fabricated according to specifications described by the National Association of Meat Purveyors (NAMP, 2007). Canadian back loins (NAMP #414) were obtained 1 d post mortem. Four 2.54 cm chops were cut, vacuum packaged, stored at 4° C, and aged for 1, 7, 14, or 21 days post mortem. At the end of each aging period, chops were frozen at -20°C and held until further analysis. Twenty-four hours prior to analysis, chops were removed

from the freezer and held at 4° C to thaw. Chops were trimmed of excess fat and cooked on 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., Barrington, IL). Chops were allowed to cool to 25° C, and six 1.25 cm 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 six cores. Shear force was reported as the average of the six cores. Cook loss was determined by weighing chops used for shear force immediately before and after cooking. Reported values are weight lost during cooking as a percentage of initial weight.

3.3.3 Sensory Evaluation and Star Probe

Loin sections remaining after the removal of the 4 chops used for shear force analysis were aged for 10 d, frozen and shipped to Iowa State University for sensory evaluation. Panels consisted of eight members who were trained according to the guidelines of the American Meat Science Association (AMSA, 1995) Eight samples were evaluated per panel providing a total of 24 panels. Panelists were separated by booths and evaluated the chops under red lighting. Water and unsalted crackers were provided between each sampling. Panelists were instructed to remain consistent with either swallowing or expectorating samples. Loins were cooked in a 176°C oven until loins reached an internal temperature of 70°C. Three 2.54 cm chops were cut from each loin, 2 chops for sensory evaluation and 1 chop for star probe. Panelists evaluated chops for

tenderness, juiciness, chewiness, boar aroma, pork flavor, and off-flavor on a 15 cm unstructured line scale; where 0 cm represented the least intense for each parameter and 15 cm represented the most intense for each parameter. Panelists were not required to taste samples if they found boar aroma too offensive.

For star probe force, samples were compressed using a star-shaped probe similar to methods described by Huff-Lonergan, Baas, Malek, Dekkers, Prusa & Rothschild (2002). The probe was pushed into the sample until the chop was compressed to 20% of its original thickness. This process was repeated at least three times at least three different locations on the chop. The average force required for the compression (peakload) value was recorded for each sample.

3.3.4 Statistical Analysis

Pen served as the experimental unit for all traits measured. Therefore, data from individual animals were averaged by pen. Data were analyzed as a 1-way ANOVA using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). The single fixed effect in the model was treatment (IC pigs, IC+RAC, PC pigs, intact males, and gilts). Replication by block interaction was considered a random variable. Assumptions of ANOVA were tested with Levene's test and Brown and Forsythe for homogeneity of variances. Normality of residuals was tested using the Univariate procedure of SAS. Means were separated using the PDIFF option. Differences were deemed significant at $P < 0.05$.

Warner-Bratzler shear force and cook loss data were collected on the same experimental unit (loin muscle of a single pig then averaged across pen) at 4 different post-mortem ages and thus were analyzed with Mixed procedure of SAS (SAS Institute, 2004) as repeated measures. An unstructured covariance structure was used based on Akaike's information criteria. The fixed

effects in the model were treatment and day of post-mortem age. Replication by block interaction was included as a random variable.

Study 2

Color stability of fresh pork chops and quality of enhanced loins from immunologically castrated pigs

3.3.5 Animal selection

Pigs used for this study were selected from a larger experiment in which approximately 1000 pigs of commercial breeding comparable to those used in industry were allotted to a wean-to-finish building. Treatments from the larger study included PC pigs fed 0.55% standard ileal digestible (SID) lysine and IC pigs fed 0.55% and 0.65% SID lysine for approximately 7 weeks prior to slaughter. Diets were formulated to meet or exceed NRC requirements for physically castrated pigs. As such, PC pigs were fed 0.55% SID lysine and one treatment of IC pigs were fed similarly. However, to maximize growth of IC pigs, more lysine is required (Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al., 2011), therefore, one treatment of IC pigs included 0.65% SID lysine. These two lysine levels represent commercially applicable diets for PC and IC pigs. Physically castrated pigs were castrated at or before 7 days of age, while IC pigs received the first injection of Improvest[®] at ~4 months of age (16 weeks) and the second injection at 20 weeks of age. Pigs were transported to a commercial facility and harvested under inspection at an approximate ending live weight of 120 kg. Carcasses from the 2 pigs closest to the pen mean weight (2 pigs per pen; 7 pens per treatment group; n = 42) were transported to University of Illinois Meat Science Laboratory for further analysis. Upon arrival, carcasses were fabricated according to specifications described by the National Association of Meat Purveyors (NAMP, 2007). Canadian back loins (NAMP #414) were obtained.

3.3.6 *Evaluation of fresh pork chops in simulated retail display*

Two 2.5 cm chops were collected from the sirloin end of each Canadian back loin, placed on trays, PVC overwrapped (O_2 Transmission Rate = 11627.91 cc/m²/d), and displayed under constant light (883 lx) at 4°C for 7 days. On days 1, 3, 5, and 7, a trained, five-person panel evaluated chops for discoloration and overall color. Discoloration was evaluated using a 10 cm line scale (reference marks at 0, 2.5, 5, 7.5, and 10 cm), where every 1 cm represented 10% discoloration of both chops on the tray. Panelists also evaluated chops for overall color using a 10 cm unstructured line scale where 0 represented a color score 1 (very pale), 5 represented a color score 3.5 (average), and 10 represented a color score 6 (very dark) according to NPPC color standards (NPPC, 1999). Values recorded were then converted to the NPPC 6 point color scale using the following equation: 0.5 (color score) + 1. At the same evaluation times, color was measured on one chop using a Minolta CR-400, (Minolta Camera Company, Osaka, Japan; D65 light source and 0° observer) to obtain L*, a*, and b* values. To evaluate discoloration, a Hunter Lab Miniscan XE (Model 45/0-L; Hunter Associates Laboratory Inc., Reston, VA, USA) illuminant D65 and a 10° observer was used following methods similar to Holmer, McKeith, Boler, Dilger, Eggert, Petry, et al. (2009). The difference in reflectance at R630-R580 wavelengths recorded by the Hunter Lab Miniscan XE has been used as an objective measure of visual redness and discoloration (Zhu & Brewer, 1998; Holmer, McKeith, Boler, Dilger, Eggert, Petry, et al., 2009) as the reflectance spectrum at 630 corresponds to that of oxymyoglobin (pinkish red) and the reflectance spectrum at 580 corresponds to that of metmyoglobin (brown). Thus, the difference between the two wavelengths is discoloration and a good indicator of color stability (Strange, Benedict, Gugger, Metzger, & Swift, 1974). Values were recorded on the same chop each day for objective color.

3.3.7 Enhanced loin preparation

After two chops were collected for simulated retail display, the remaining loin sections were paired by pen, cut in half, and each half was assigned to either control (non-enhanced) or enhanced treatment. Because there were two pigs from each pen and pen served as the experimental unit, loin halves were assigned to treatments such that each pen had both a sirloin end and a blade end of the loin represented for both control and enhanced treatments. Enhanced loin halves were pumped to a target 110% of green weight using a 3.5% salt and 3.5% phosphate solution with the target amount being 0.35% salt and 0.35% phosphate in the final product. Loins were weighed before and after pumping to calculate pump uptake. Pump uptake was calculated using the following equation: $[(\text{pumped weight} - \text{green weight}) / \text{green weight}] \times 100$. After pumping, loins were vacuum-packaged and aged at 4°C for 7 days. After aging, three 2.5 cm chops, one each for sensory evaluation, Warner-Bratzler shear force and star probe force, were collected. Chops were frozen at -20°C and stored until further evaluation.

3.3.8 Sensory characteristics of enhanced loins

Sensory evaluation was conducted on chops using a trained panel composed of individuals from the University of Illinois Meat Science Laboratory. Panels consisted of six members who were trained according to the guidelines of the American Meat Science Association. Six samples were evaluated per panel providing a total of 14 panels. Chops were allotted into panels such that each panel contained matched sets of control and enhanced samples from experimental units (pens). Panelists were separated by booths and evaluated chops under red lighting. Water and unsalted crackers were provided between each sample. Panelists were instructed to remain consistent with either swallowing or expectorating samples. Chops were cooked similarly to cooking methods for WBSF in study 1. Panelists evaluated chops for tenderness, juiciness, and

off-flavor on a 15 cm unstructured line scale anchored at the center and both ends where 0 cm represented extremely tough, very dry, and no off flavor, and 15 cm represented extremely tender, extremely juicy, and intense off-flavor. Data from panelists were averaged by chop and then averaged by pen within treatment.

3.3.9 Warner-Bratzler shear force (WBSF) and star probe force

Chops were cooked similarly to those for shear force analysis of Study 1 and weighed before and after cooking to determine cook loss. After cooking, chops were handled similarly to WBSF in study 1; however, only four 1.25 cm cores were sheared. Star probe evaluations were also handled similarly to star probe force in study 1.

3.3.10 Statistical Analysis

Pen served as the experimental unit for all traits measured. Therefore, data from individual animals were averaged by pen. Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Color during display was analyzed as repeated measures over time using an unstructured (UN) covariate matrix based upon goodness of fit analysis using Akaike's information criterion to minimize variance. Therefore, the statistical model included the fixed effects of treatment (PC pigs fed 0.55% SID lysine, IC pigs fed 0.55% SID lysine, and IC pigs fed 0.65% SID lysine), display time, and their interaction. Enhancement data were analyzed as a split plot design where treatment served as the whole plot, and enhancement group (control or enhanced loin sections) served as sub-plot, and their interaction served as fixed effects of the model. Assumptions of ANOVA were tested with Levene's test and Brown and Forsythe for homogeneity of variances. Normality of residuals was tested using the Univariate procedure of SAS. Means were separated using the PDIFF option employing a Tukey's adjustment for multiple comparisons. Differences were deemed significant at $P < 0.05$.

3.4. RESULTS

Study 1

3.4.1 Sensory characteristics and instrumental tenderness

Treatments did not differ in juiciness ($P=0.59$), tenderness ($P=0.19$), chewiness ($P=0.67$), or off flavor ($P=0.11$) (Figure 6B, 6C, 6D, 6F). However, boar aroma was the most intense in intact males ($P<0.01$) when compared to all other treatments (Figure 6A). Pork flavor was the more intense in gilts ($P<0.01$) compared with intact males. Pork flavor was not different between PC pigs, IC+RAC pigs and gilts and similar among PC, IC+RAC, and intact males (Figure 6E).

Star probe was not affected by treatment ($P=0.24$) (Figure 7A). At d 1 of aging, WBSF did not differ among treatments (Figure 7B). At all other time points, however, WBSF was reduced in IC pigs compared with IC+RAC, intact males, and gilts. Shear force, however, was similar between IC and PC pigs at all time points.

Study 2

3.4.2 Color evaluations of fresh pork chops in simulated retail display

Discoloration of chops increased ($P<0.01$) with display time (Figure 8A). However, there were no differences ($P=0.42$) between treatments nor was there an interaction ($P=0.71$) between treatment and display time; therefore, with time, all treatments discolored in a similar manner. For color, there was an interaction ($P=0.02$) of treatment and display time (Figure 8B). Over time, color became darker but not all treatments darkened at the same rate. In general, IC pigs fed 0.65% SID lysine had the darkest color while PC pigs had the lightest ($P=0.02$). However, overall changes in color scores were small, ranging from a 3 to a 4 on the NPPC scale (NPPC, 1999).

Display time affected ($P < 0.01$) Minolta color values. L^* values decreased from days 1 to 5 indicating chops got darker over time (Figure 9A). On day 7, however, L^* values increased ($P < 0.01$) for all treatments. L^* values were also affected by treatment ($P = 0.03$). Averaged across all days, IC pigs fed 0.65% lysine were darker ($P = 0.03$) than PC pigs, however, within day, there were no differences between treatments. Treatment did not affect a^* values ($P = 0.10$), although there was a display time effect ($P < 0.01$) (Figure 9B). The a^* values increased from day 1 to 5 indicating chops were redder; however, at day 7 a^* decreased. Treatment did affect b^* values ($P = 0.04$) with PC pigs recording the largest value and IC pigs fed 0.55% SID lysine recording the smallest (Figure 9C). Furthermore, from day 1 to 3 and on day 5, b^* values increased but then decreased on day 7. There was no interaction ($P > 0.05$) between treatment and display time for L^* , a^* , or b^* (Figure 9).

The difference in reflectance was not affected ($P = 0.69$) by treatment and did not have an interaction ($P > 0.05$) between display time and treatment (Figure 9D). The difference in R630-R580 wavelength did change over time ($P < 0.05$) where the difference in reflectance increased from day 1 to 3, remained steady at day 5, and then decreased at day 7. This indicates that overall, chops got redder from day 1 to 5 and then had the most discoloration (i.e. most metmyoglobin) on day 7.

3.4.3 *Sensory and quality characteristics of enhanced and non-enhanced loins*

Green and pumped weights of IC pigs fed 0.55 and 0.65% SID lysine were greater ($P < 0.05$) than those of PC pigs (Table 5), however, there were no differences ($P > 0.05$) in pump uptake between treatments. Treatment also did not affect juiciness ($P = 0.91$), tenderness ($P = 0.94$), or off flavor ($P = 0.45$) of chops (Figure 10). However, as expected, enhanced chops were juicier ($P < 0.01$) and more tender ($P < 0.01$), but had more off-flavor than non-enhanced chop ($P < 0.01$).

There were no interactions of treatment and enhancement for juiciness ($P=0.54$), tenderness ($P=0.58$), or off flavor ($P=0.09$). Treatment also did not affect cook loss ($P=0.65$), star probe ($P=0.86$), or shear force ($P=0.50$) (Figure 11). However, enhanced chops had an approximately 21% reduction in cook loss, 0.61 kg reduction in shear force value, and a 0.76 kg reduction in star probe force value when compared to non-enhanced chops ($P<0.01$). There were no interactions between enhancement and treatment for cook loss ($P=0.81$), star probe ($P=0.40$), or shear force ($P=0.99$).

3.5. DISCUSSION

3.5.1 Color evaluations of fresh pork chops in simulated retail display

Color is an important cue for consumers when they select meat to purchase (Bredahl, Grunert, & Fertin, 1998), and consumers perceive discolored meat negatively (Troy & Kerry, 2010). Therefore, it was important to determine whether color or discoloration development differed between IC and PC pigs. There were no differences in subjective or objective discoloration evaluations between IC and PC pigs, indicating immunological castration did not affect discoloration of fresh pork chops during storage. Nevertheless, differences in overall color were noted between IC and PC pigs. Visual evaluations and L^* measurements of color indicated that IC pigs fed 0.65% lysine were darker than PC pigs, but similar to IC pigs fed 0.55% SID lysine. However, all values fell within an acceptable range of pork color. When consumers were asked to evaluate pale, soft, and exudative, normal, and dark, firm, and dry pork, they rated normal colored pork from 2.6 - 3.6 on a five point scale (Brewer, Lan, & McKeith, 1998). This would correspond to a 3.1 – 4.3 on the NPPC 6 point scale resulting in color ratings similar to our study. Likewise, all chops fell in the normal pork color L^* range, defined as 43-50 (Joo, Kauffman, Kim, & Kim, 1995). Overall, the minor differences between IC pigs and PC pigs with

regard to the color of fresh pork chops during storage should not limit usage of loin chops from IC pigs as all values are within the ranges of acceptable color.

3.5.2 Sensory characteristics and quality of enhanced and non-enhanced loins

Previous work by Font i Furnols, González, Gispert, Oliver, Hortós, Pérez, et al. (2009) detected no differences in sensory characteristics (odor, flavor, or texture) between IC and PC pigs. However, pigs in that study were not only younger (~170 d) but were also slaughtered at 4 weeks after second injection of Improvest. In typical US production, pigs are slaughtered at older ages, heavier weights and longer times after second Improvest injection. Therefore, pigs from study 1 were slaughtered at a common ending live weight of 130 kg at 4.5, 5.5 and 6.5 week after second injection. Thus, the first pull of the barn was at 173 d of age while pull two and three were at 180 d and 187 d of age. Pigs from study 2 were harvested at 7 weeks after second injection at 189 d of age. With the exception of the first slaughter time from study 1, pigs from our studies were older, heavier, and further from second injection. Furthermore, loins from study 2 were enhanced. Nevertheless, sensory evaluations would indicate that loins from IC and PC pigs do not differ even in pigs that are more commonly represented in United States pork production systems.

Tenderness is one of the more important sensory characteristics in determining palatability of fresh pork (Enfält, Lundström, Hansson, Lundeheim, & Nyström, 1997). In these studies, tenderness was measured in several ways including star probe, WBSF and sensory panels. In each case, there were no differences in tenderness between IC and PC pigs, with one exception. In chops aged for 21 days, shear force was increased in IC pigs fed RAC compared with IC pigs and PC pigs but shear force of IC pigs fed RAC was similar to gilts. Furthermore, pork from all 5 treatments aged 7 days or more would generally be considered tender with shear force values

between 2.7-3.6 and, thus, would be acceptable to consumers as the threshold is 3.0-3.9 kg (Van Oeckel, Warnants, & Boucqué, 1999). These results confirmed the work of Boler, Kutzler, Meeuwse, King, Campion, McKeith, et al. (2011) who also reported no differences between IC and PC pigs for Warner-Bratzler shear force of non-enhanced pork loin chops aged 14 days. Furthermore, there were no differences between IC and PC pigs with regard to other sensory characteristics including juiciness and flavor. Finally, enhancement increased juiciness and tenderness of both IC and PC loin chops in a similar fashion indicating that no distinction is needed between castrations methods when considering pork for enhancement.

3.6. CONCLUSION

According to the Pork Checkoff Quick facts ("Quick Facts: The pork industry at a glance," 2009), 10.2% of pork is consumed as fresh pork chops. Thus, it is imperative to understand the effects a technology such as immunological castration may have on the overall quality of pork loin chops. In these studies, immunological castration did not affect color stability of fresh pork loin chops or quality of enhanced or fresh pork loin chops. Immunological castration also reduced boar aroma to levels similar to PC pigs and gilts. Finally, immunological castration had no detrimental effect on tenderness of pork loin chops. Therefore, pork from immunologically castrated pigs can be used similarly to that of physically castrated pigs without detrimental effects on quality.

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3.8. FIGURES AND TABLES

Figure 6: Sensory panel ratings of boar aroma (A), juiciness (B), tenderness (C), chewiness (D), pork flavor (E), and off flavor (F) of fresh loins from immunologically castrated (IC) pigs, IC pigs fed ractopamine hydrochloride (RAC), physically castrated (PC) pigs, gilts and intact male (IM)

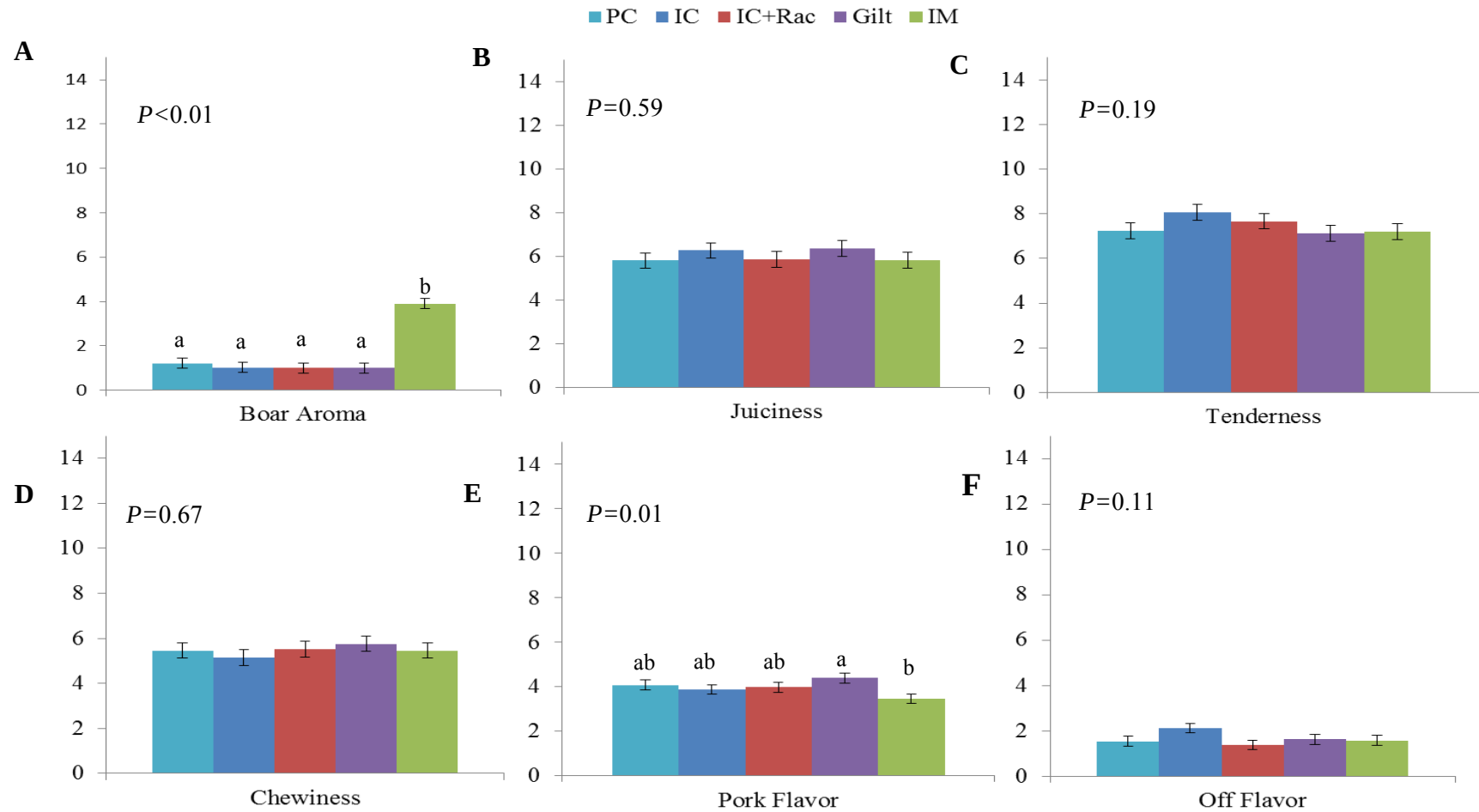


Figure 7: Star probe force of fresh loins aged 10 days postmortem (A) and Warner-Bratzler shear force values of pork chops aged 1, 7, 14, 21 days postmortem (B) from immunologically castrated (IC) pigs, IC pigs fed ractopamine hydrochloride (RAC), physically castrated (PC) pigs, gilts and intact male (IM)

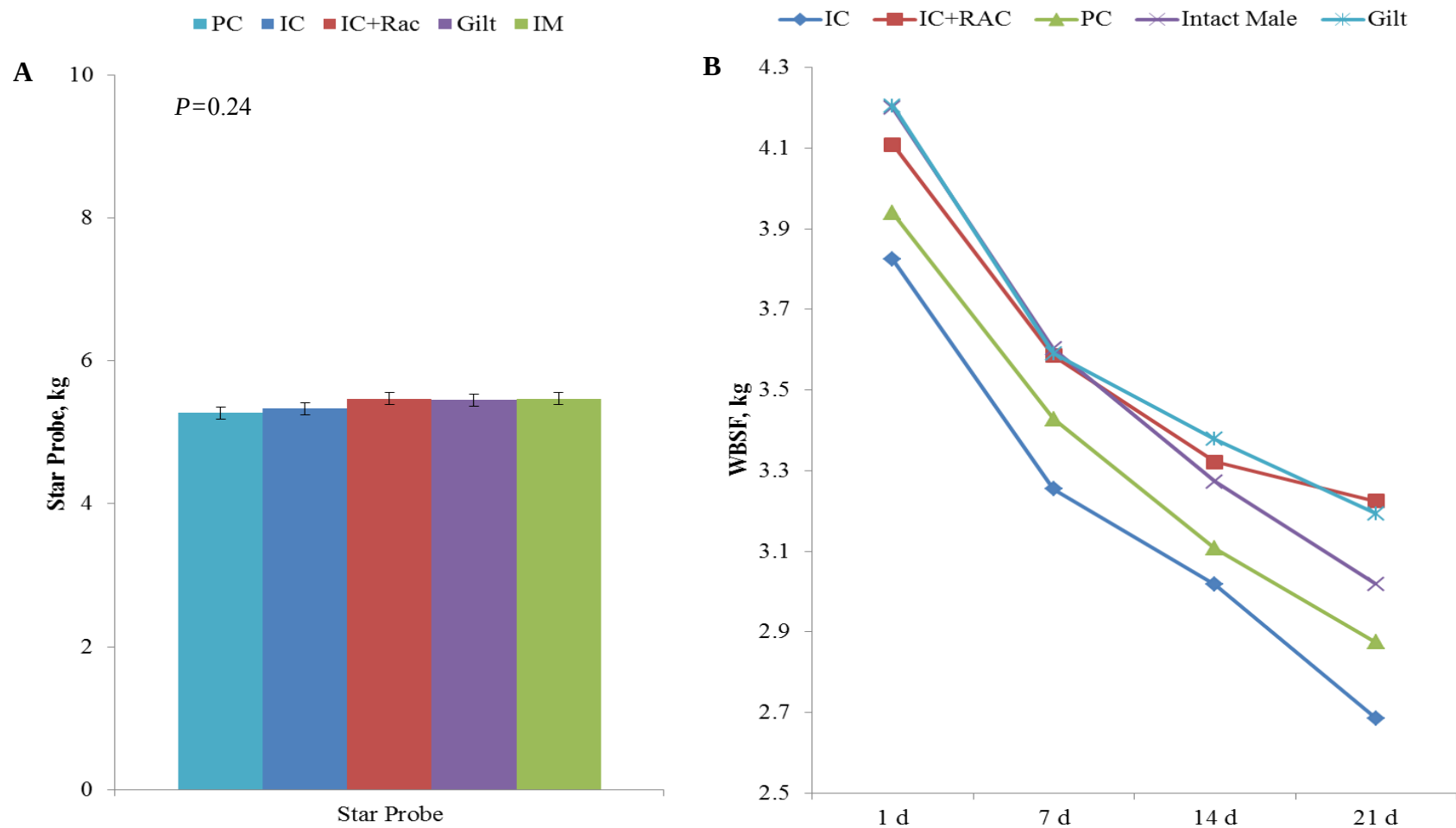


Figure 8: Discoloration (A) and overall color (B) of fresh pork chops from immunologically castrated (IC) and physically castrated (PC) pigs. Treatments included IC pigs fed 0.55% standardized ileal digestible (SID) lysine, IC pigs fed 0.65% SID lysine, and PC pigs fed 0.55% SID lysine

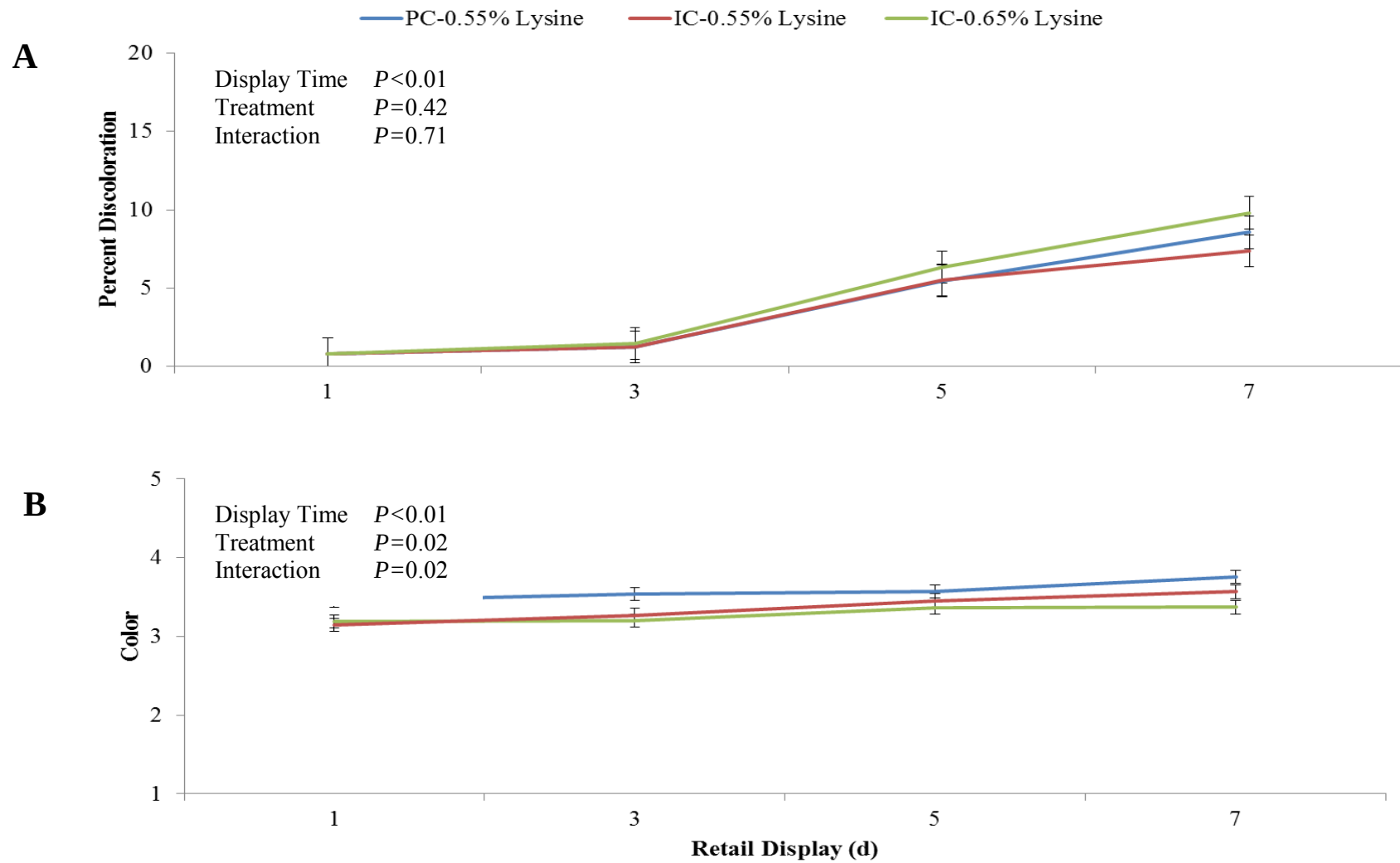


Figure 9: L* (A), a* (B), b* (C), and R630-R580 (D) values of fresh pork chops from immunologically castrated (IC) and physically castrated (PC) pigs. Treatments included IC pigs fed 0.55% standardized ileal digestible (SID) lysine, IC pigs fed 0.65% SID lysine, and PC pigs fed 0.55% SID lysine

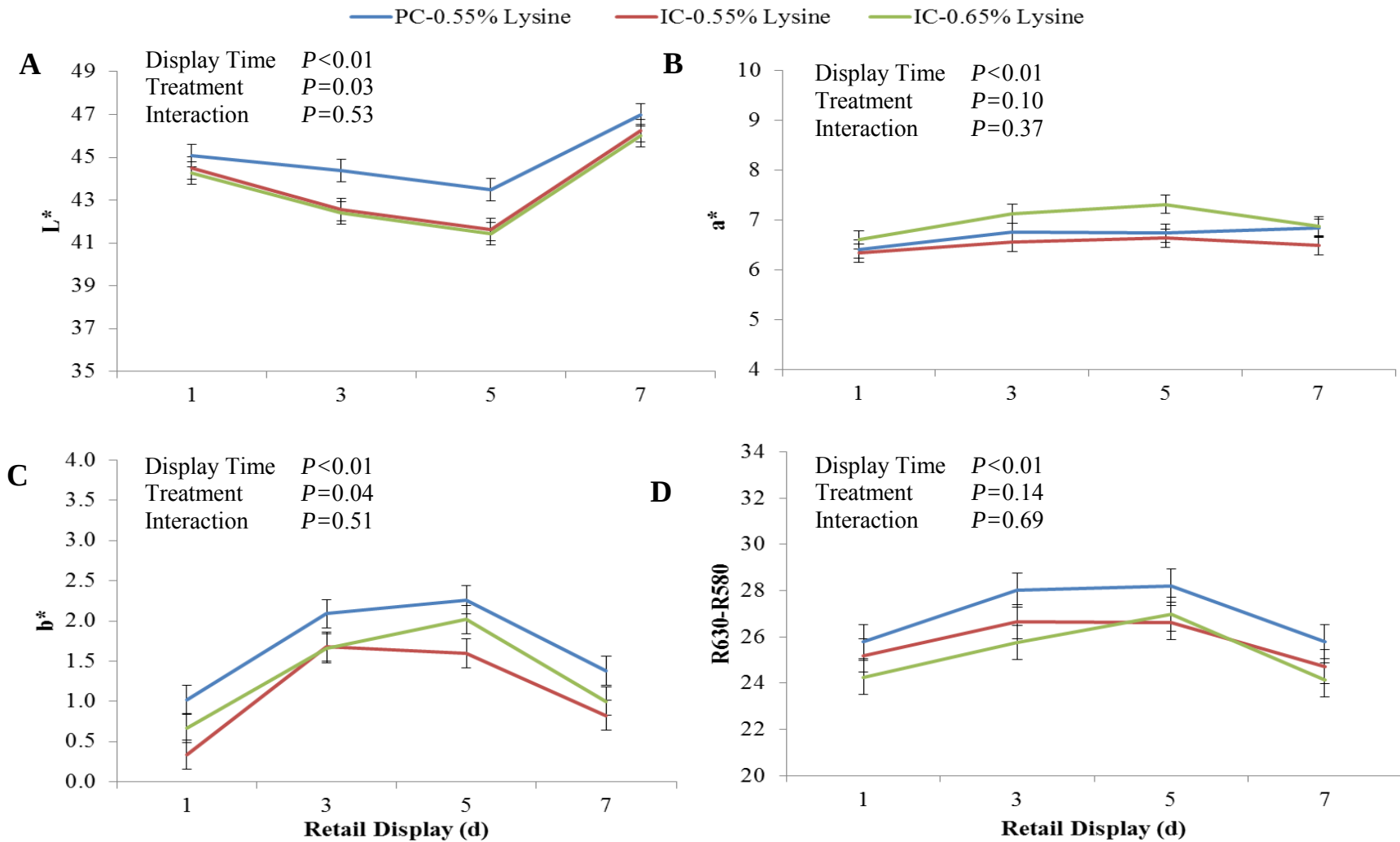


Figure 10: Sensory panel ratings of juiciness (A), tenderness (B), and off flavor (C) of pork chops from immunologically castrated (IC) and physically castrated (PC) pigs. Treatments included IC pigs fed 0.55% standardized ileal digestible (SID) lysine, IC pigs fed 0.65% SID lysine, and PC pigs fed 0.55% SID lysine

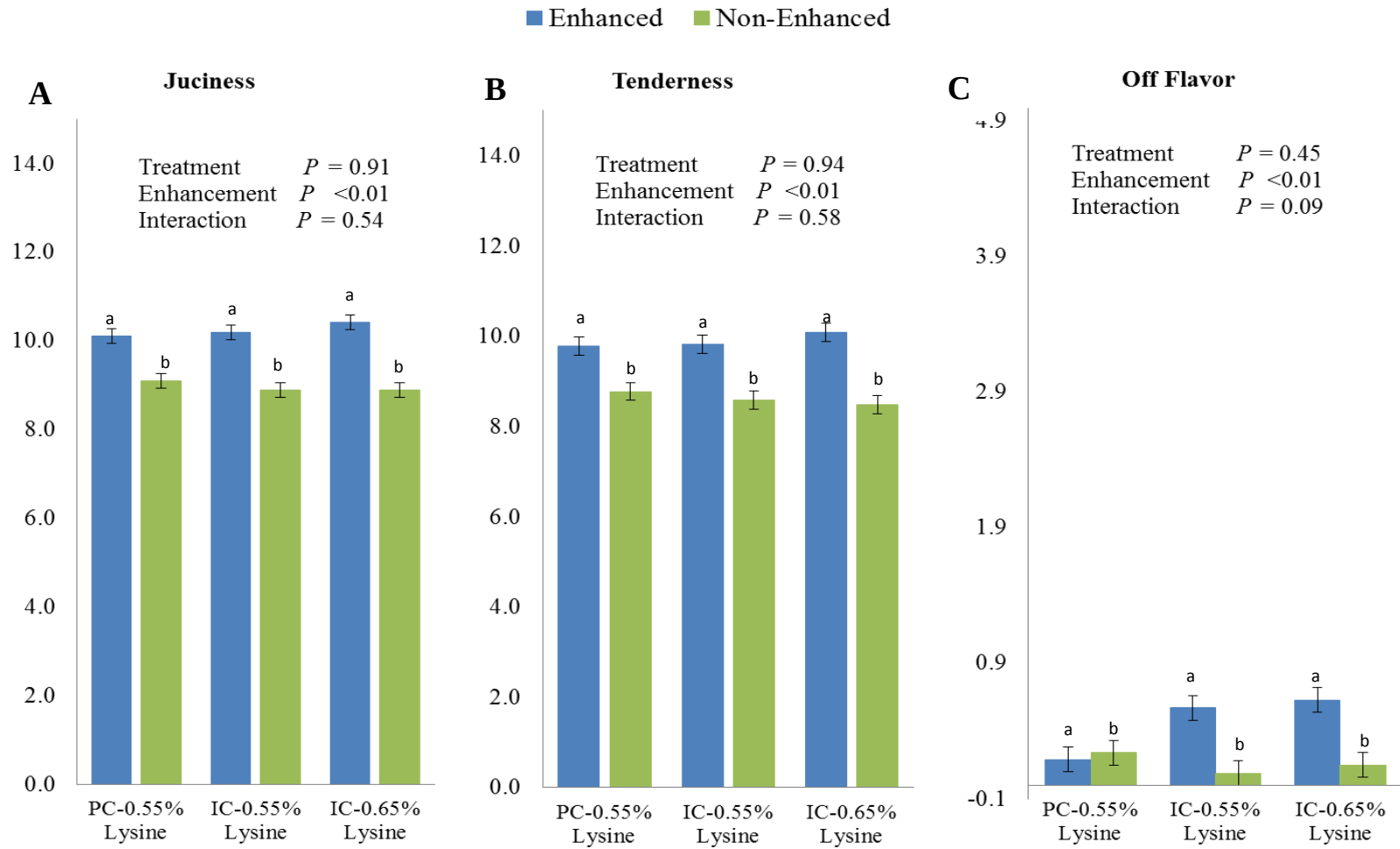


Figure 11: Effect of immunological castration and enhancement on the cook loss (A), star probe force (B), and Warner-Bratzler shear force (C) of pork chops from immunologically castrated (IC) and physically castrated (PC) pigs. Treatments included IC pigs fed 0.55% standardized ileal digestible (SID) lysine, IC pigs fed 0.65% SID lysine, and PC pigs fed 0.55% SID lysine

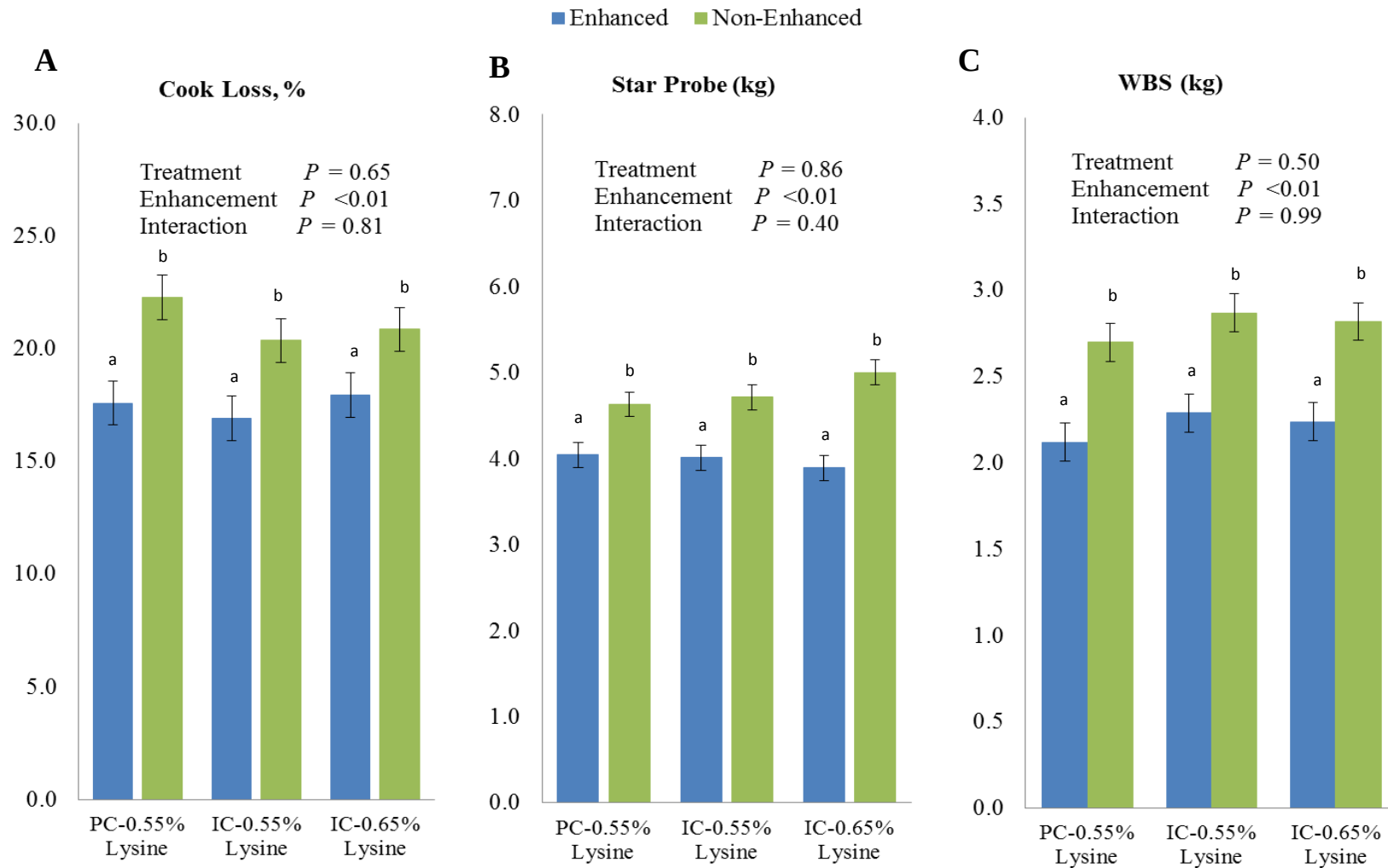


Table 4. Statistical summary of shear force differences of immunological castrated (IC) pigs, IC pigs fed ractopamine hydrochloride (RAC), physical castrated (PC) pigs, gilts and intact males (IM)

Treatment	Postmortem Aging Day			
	1	7	14	21
IC Pigs		a	a	a
IC Pigs + RAC		b	bc	c
Physical Castrate		ab	ab	ab
Entire Male		b	bc	bc
Female		b	c	c

Shearforce values within a column not sharing a common superscript differ $P < 0.05$

Table 5. Effects of treatment on the green and pumped weight and pump uptake

Item	PC	IC		SEM
	0.55% Lysine	0.55% Lysine	0.65% Lysine	
Green Wt	1.59 ^b	1.95 ^a	1.85 ^a	0.066
Pumped Wt	1.75 ^b	2.15 ^a	2.03 ^a	0.074
% Uptake	10.18	10.66	9.99	0.395

a,b means within row lacking common superscripts are different
(P<0.05)