Case report

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Performance of immunologically castrated pigs at a commercial demonstration farm over 3.5 years

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Summary

A longitudinal study was conducted to evaluate performance and mortality of male pigs following immunological castration with a commercial gonadotropin releasing hormone analog-diphtheria toxoid conjugate (Improvest). Twelve groups of intact male weanling pigs (approximately 250/group) were delivered to a single barn over 3.5 years. Two doses of Improvest were administered subcutaneously, with the first dose given at 10 to 15 weeks of age and the second dose given at 18 to 19 weeks of age. Wean-to-market average daily gain (ADG) among the 12 test groups ranged from 0.83 to 0.99 kg/day (mean, 0.89 kg/day), feed efficiency (FE) ranged from 2.10 to 2.50 (mean, 2.24), and mortality ranged from 1.61% to 7.20% (mean, 3.25%). When lysine levels were increased by approximately 12% (groups 6-12), ADG increased by 6.3% and FE improved by 4.1%. Except for group 7 mortality, performance of all groups surpassed two 2016 industry benchmarks for ADG, FE, and mortality (National Pork Board Top 25% Producers and MetaFarms). Immunologically castrated barrows performed similarly with or without antimicrobial feed additives under these conditions. This study demonstrated that immunological castration delivered consistent high performance and livability that exceeded industry benchmarks.

Keywords: swine, castration, immunological castration, feed efficiency, Improvest

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Resumen - Desempeño de cerdos inmunológicamente castrados en una granja comercial de demostración durante 3.5 años

Se desarrolló un estudio longitudinal para evaluar el desarrollo y mortalidad de cerdos machos después de la castración inmunológica con un conjugado comercial que libera un análogo de la hormona gonadotropina con un toxoide de difteria (Improvest). Doce grupos de machos intactos destetados (aproximadamente 250/grupo) fueron colocados en un solo edificio durante 3.5 años. Se administraron dos dosis subcutáneas de Improvest, la primera dosis se aplicó entre las 10 y 15 semanas de edad y la segunda dosis se aplicó 18 a 19 semanas de edad. La ganancia diaria de peso (ADG por sus siglas en inglés) de destete a sacrificio varió en los 12 grupos entre 0.83 a 0.99 kg/día (media, 0.89 kg/día), la eficiencia alimenticia (FE, por sus siglas en inglés) varió entre 2.1 a 2.5 (media, 2.24), y la mortalidad varió entre 1.61% a 7.20% (media 3.25%). Cuando los niveles de lisina se aumentaron aproximadamente en 12% (grupos 6-12), la ADG aumento en 6.3% y la FE mejoró en un 4.1%. Excepto por la mortalidad del grupo 7, el desempeño de todos los grupos sobrepasó dos evaluaciones comparativas de ADG, FE, y mortalidad (el 25% de los mejores productores del National Pork Board y MetaFarms). Bajo estas condiciones, los machos castrados inmunológicamente se desempeñaron de manera similar con o sin antibióticos en el alimento. Este estudio demostró que la castración inmunológica produjo de manera consistente, alto desempeño y sobrevivencia que sobrepasó las evaluaciones comparativas de la industria.

Résumé - Performances des porcs castrés immunologiquement sur une ferme commerciale de démonstration pendant une période de 3.5 ans

Une étude longitudinale a été menée afin d'évaluer les performances et la mortalité de porcs mâles à la suite de la castration immunologique avec un conjugué commercial d'analogue de l'hormone relâchant la gonadotrophine et de toxoïde de la diphtérie (Improvest). Douze groupes de porcelets mâles intacts (environ 250/groupe) furent livrés à une ferme unique pendant 3.5 ans. Deux doses d'Imrovest furent administrées par voie sous-cutanée, la première dose donnée à 10 à 15 semaines d'âge et la seconde dose donnée 18 à 19 semaines d'âge. Le gain moyen quotidien (ADG) entre le sevrage et la mise en marché parmi les 12 groupes variaient de 0.83 à 0.99 kg/jour (moyenne, 0.89 kg/jour), l'efficacité alimentaire (FE) variait de 2.10 à 2.50 (moyenne de 2.24), et la mortalité variait de 1.61% à 7.20% (moyenne, 3.25%). Lorsque les quantités de lysine furent augmentées par approximativement 12% (groupes 6-12), l'ADG augmenta de 6.3% et la FE s'améliora de 4.1%. À l'exception de la mortalité dans le groupe 7, les performances de tous les groupes ont surpassé deux valeurs repères de 2016 pour l'ADG, la FE, et la mortalité (National Pork Board Top 25% Producers et MetaFarms). Les performances des castrats immunologiques étaient similaires avec ou sans ajout d'antibiotiques dans l'alimentation dans les présentes conditions expérimentales. Cette étude a démontré que la castration immunologique permettait d'obtenir de manière constante d'excellentes performances et une viabilité qui surpasse les valeurs repères de l'industrie.

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A growing body of research and field experience has confirmed that immunological castration of male pigs has several advantages compared with physical castration in commercial pork production. The immunological castration agent in greatest use in the United States and worldwide is a synthetic analog of gonadotropin releasing hormone (GnRH) conjugated with diphtheria toxoid (Improvest, Zoetis). Improvest is an FDA-approved, 2-dose, nonhormonal product that is given to intact male pigs to reduce unpleasant odor in the meat. After the second dose, the GnRH analog-conjugate consistently stimulates high levels of antibodies that neutralize endogenous GnRH,[1] the hormone that regulates testicular function and production of testicular steroids. As a result, production and accumulation of the off-odor compounds androstenone and skatole are suppressed in immunized boars, resulting in pork that has improved sensory appeal to consumers. Consumer perception studies have shown that anti-GnRH immunization was 100% and 99% effective in suppressing androstenone and skatole, respectively, below sensory levels.[1] Physically and esthetically, cooked pork from immunologically castrated (IC) barrows has been shown to be no different than meat from gilts or physically castrated (PC) barrows and has superior qualities to meat from intact, sexually normal postpubertal boars.[1-3]

Immunological castration has been shown to consistently improve feed efficiency (FE). By functioning as intact boars until several weeks before marketing then transitioning to physiological castrates following the second anti-GnRH dose, IC barrows grow faster and more efficiently than PC males for the majority of the grow-finish period. Studies conducted in experimental and production settings have shown that, compared to PC pigs, IC counterparts have increased carcass leanness, greater cutting yields, and more efficient feed conversion.[1,4-12] More efficient feed utilization has the potential to contribute to environmental sustainability by reducing the carbon footprint associated with pork production.[13] Immunological castration also avoids animal discomfort, stress, morbidity, mortality, and performance losses associated with physical castration. A meta-analysis found that IC barrows (n = 2197) had a 1.6% lower castration-to-weaning mortality rate (4.1% [0.81% SE] vs 5.7% [1.08% SE]; $P = 0.02$) compared to PC barrows (n = 2196), a 39% relative improvement and a strong indication that immunological castration can contribute to lower pre-weaning death loss.[14] Within a week after the second dose and lasting at least 10 weeks, immunological castration reduces aggressive and sexual behavior in male pigs, minimizing aggression-related skin and carcass lesions.[15] Avoidance of aggression, fighting, and sexual behavior in IC pigs prior to marketing not only contributes to more active eating behavior and greater ADG but avoidance of pre-slaughter environmental and physiological stress responses that result in suboptimal carcass pH associated with poor quality pork.[1]

Most studies demonstrating the advantages of IC have been single experiments performed during one growing period. The purpose of this case report is to share the results of a long-term evaluation (3.5 years) of performance and mortality of IC barrows raised at a single site in the Midwest United States. As this was a real-world production setting, management and nutrition changes occurred over the 3.5 years. The impact of these changes is described.

Case description

The study was conducted at a commercial swine facility in Indiana from January 2014 to July 2017 under the supervision of a licensed veterinarian utilizing management practices specified in the Animal Welfare Act (7 USC 54) and in the Federation of Animal Science Societies' 2010 Guide for the Care and Use of Animals in Research and Teaching. Nursery and finishing rooms each consisted of 10 pens per room. Approximately 25 intact male pigs were housed in each pen. Nursery and finisher pen dimensions were 5.7 × 1.8 m and 6.1 × 2.9 m, respectively. This resulted in 0.42 and 0.71 m^2/pig, respectively. Each room had a computer-controlled tunnel ventilation system with ceiling inlets.

Animals originated from a 400-sow farrow-to-wean herd sired by a PIC line 337 boar. The source herd was negative for porcine reproductive and respiratory syndrome virus (PRRSV). Periodic oral fluids testing confirmed that study pigs were PRRSV-negative for the 3.5-year study duration. Intact, male pigs from a 2-week weaning period (average weaning age was 19-25 days) were obtained from the source herd in consecutive groups of 250 pigs. Upon arrival, all pigs were individually ear tagged, which enabled individual antibiotic treatments to be linked to specific animals. Pigs were housed in the nursery until approximately 51 days after weaning, then moved in an all-in-all-out, wean-to-market pig flow to the finishing room, where they were maintained until marketing.

Husbandry activities were performed by local Future Farmers of America students working in pairs, usually for 4 to 5 months. The students were trained in all areas of swine husbandry and supervised by the attending veterinarian. Each pen was inspected twice daily for animal welfare and functionality of feed and watering systems. All treatment decisions were made by the attending veterinarian. Individual treatments were recorded for each pig. Feed was hand-weighed, and weights recorded by pen to calculate daily feed intake.

Wean-to-finish diets were modified on a stepwise basis by body weight to accommodate the changing nutritional requirements and feed consumption patterns of test pigs and to maximize the production returns associated with anti-GnRH immunization. All diets met National Research Council (NRC) recommendations. Groups 1 to 5 were fed rations formulated according to the 2013 Improvest nutritional guidelines, which recommends lysine at 112% of contemporary PC barrows.[16] Rations for groups 6 to 12 were formulated according to the updated 2014 Improvest nutritional guidelines, which recommends lysine at 125% of contemporary PC barrows.[16] Lysine changes were accompanied by concomitant phosphorus adjustment to maintain calcium to phosphorus ratios consistent with NRC standards. Additional lysine was added to achieve greater lean tissue deposition, optimum fat-to-lean tissue characteristics, and improved cutting yields in IC pigs, as shown in previous studies.[4,17-19] Following the second anti-GnRH dose, dietary lysine was decreased for all groups as immunized pigs assumed barrow-like behaviors and increased their feed consumption.[17]

To control infections, pigs in groups 1 to 7 were given antimicrobial feed additives at therapeutic levels until they reached 50 kg in weight. From weaning to 18 kg, feed contained chlortetracycline (400 g/ton) and tiamulin hydrogen fumarate (35 g/ton). From 19 to 27 kg, feed contained lincomycin hydrochloride (100 g/ton). From

28 to 50 kg, feed contained lincomycin hydrochloride (40 g/ton). Antimicrobial feed medications were discontinued in feed of groups 8 to 12.

On the day of arrival, pigs were vaccinated according to label instructions with a porcine circovirus type 2 and *Mycoplasma hyopneumoniae* combination vaccine (Fostera PCV MH, Zoetis). When clinical signs of infectious disease were evident, pigs were individually treated per label instructions with injectable antimicrobial agents (Draxxin or Excenel, Zoetis). The percentage of pigs in each group that were treated was calculated. The sow farm was routinely monitored for disease by serological and nasal swab diagnostics.

On arrival at the study site, a shipment of 125 weanling pigs was sorted into five pens of 25 pigs each. Pigs were assigned to each pen based on visual assessment of size, from largest to smallest, so that the fifth pen had the 25 smallest pigs. A second shipment of 125 pigs was received a week later and similarly sorted to complete a group of 250 pigs. The procedure was repeated for all 12 groups. Each group consisted of approximately 250 intact male pigs except for groups 3 and 5, which consisted of 80% IC pigs and 20% PC pigs (PC barrow performance is not reported here). Two 2-mL doses of commercial anti-GnRH immunizing agent (Improvest, Zoetis) were administered by subcutaneous injection to all study pigs. The first dose was administered at 10 to 15 weeks of age, followed by the second dose at 18 to 19 weeks of age. The syringe used for administering Improvest was equipped with a manufacturer-provided protective shield that minimized the potential for inadvertent user self-inoculation.

Feed consumption, average daily gain (ADG), and FE were determined for each pen and group at the end of the nursery and finishing periods. Individual pig mortality and group mortality were determined for the nursery and finishing periods and for the overall wean-to-finish period. To monitor variances in production outcomes over time, statistical process control (SPC) charts were used to assess ADG and FE by plotting the average values for each group of IC pigs enrolled during the 3.5-year study using Minitab statistical software (version 17.3.1; Minitab Inc). The software automatically generated mean, upper control limit (UCL), and lower control limit (LCL) values from the input data. The UCL and LCL were 3 sigma units above or below the average value, meaning that 99.73% of the data was located within the control limits. This control-limit range enabled quick identification of marked variances from population norms.

Performance and mortality

Wean-to-market ADG, FE, and mortality outcomes for individual groups and for the entire 12-group test population are shown in Table 1. Average daily gain ranged from 0.83 to 0.99 kg/day (mean, 0.89 kg/day), FE ranged from 2.10 to 2.50 (mean, 2.24), and mortality ranged from 1.61% to 7.20% (mean, 3.25%). Mortality was < 5% for all groups except groups 2 and 11 (5.18% and 7.20%, respectively). There was no single predominant cause for the elevated mortality rates in groups 2 and 11, which experienced pig mortality from various infectious and physical origins.

Groups fed the 125% lysine diets showed consistent improvement in ADG and FE over groups fed the 112% lysine diets (Table 2). The highest ADG (0.99 kg/day, group 6) and best FE (2.10, group 9) were observed in groups fed the 125% lysine diets. The effect of lysine on ADG and FE becomes more convincing considering that the groups with the 5 highest ADG were all fed 125% lysine diets, and the 7 groups (6-12) fed 125% lysine diets had superior FE compared to that of the 5 groups (1-5) fed the 112% lysine diet. Figures 1 and 2 provide visual demonstration that groups 6 to 12 fed the 125% lysine diet had superior FE and ADG compared to groups 1 to 5 fed the 112% lysine diet. The SPC charts show that variances in FE and ADG values from group to group remained within the upper and lower control limits regardless the dietary regimen. The ADG varied within a much narrower range for groups 1 to 5 compared to groups 6 to 12 (Figure 2).

Mortality rates were variable and without apparent associations with lysine concentration in the diet. For example, groups fed a 125% lysine diet had both the highest and lowest mortality rates, 7.20% (group 11) and 0.80% (group 6), and the mean mortality rate in groups 1 to 5 (3.25%) was virtually identical to that for groups 6 to 12 (3.26%). However, pigs fed the antibiotic-free diet (groups 8-12) had a 3.92% mortality rate, which was higher than the overall rate for all other groups, 3.25% (Table 2). Mortality varied depending on production phase (Table 3). Nursery pigs had a 1.89% (57 of 3010 pigs) mortality rate compared to a 1.39% rate for finisher pigs (41 of 2953). Of the dead nursery pigs, 71.93% had been treated with injectable antibiotics compared to 19.51% antibiotic treatment rate of dead finisher-phase pigs. Whereas mortality in nursery pigs almost always occurred in clinically sick animals, 75.6% of finishing pigs (30 of 41) died spontaneously without showing clinical signs or were euthanized due to hernia or lameness.

The antibiotic treatment rate for all nursery groups was 16.41% (494 of 3010 pigs). This figure was skewed upward by the administration of antimicrobials to 100% of the pigs in group 5 to control possible secondary bacterial infection associated with exposure to influenza A virus-swine the week prior to shipment to the study site. When group 5 was excluded, the treatment rate in nursery pigs dropped to 8.81% (243 of 2759 pigs). By the finishing phase, treatment rates for group 5 pigs had moderated and were nearly equivalent to the overall finishing population, 1.19% vs 1.15% (Table 3). Cause of death was not determined.

Discussion

This longitudinal study showed that performance and livability of IC barrows in a commercial production setting was consistent over a 3.5-year period. In most cases, results exceeded 2016 benchmark data compiled by the National Pork Board and MetaFarms (Table 2).[20, 21] Compared to 2016 National Pork Board Top 25% Producer data, pigs in our study had an 11.3% greater ADG, 9.4% better FE, and 60.6% lower mortality. Compared to MetaFarms data, pigs in our study had 20.9%, 14.3%, and 72.9% improvements in ADG, FE, and mortality, respectively. These results reflect the potential impact of consistently applying good husbandry and management practices, including immunological castration.

Removing antimicrobial feed additives from IC barrows in groups 8 to 12 had little effect on ADG, FE and mortality. The comparatively high mortality rate in pigs fed the antibiotic-free diet was due to an unexpected 7.20% death loss in group 11. When group 11 is excluded, the remaining groups fed the antibiotic-free diet had a 3.10% mortality rate, which was less than the 3.25% rate for the overall study population. As expected, additional dietary lysine fed to

Table 1: Wean-to-market performance of immunologically castrated barrows from January 2014 to July 2017

					Dietary regimen	
Group	**No. IC pigs**	**ADG (SD), kg/day**	**FE (SD)**	**Mortality (SD), %**	**Lysine, %**	**Antimicrobials**
1	251	0.86 (0.04)	2.34 (0.03)	1.99 (2.82)	112	Included
2	251	0.83 (0.05)	2.23 (0.07)	5.18 (4.48)	112	Included
3	209*	0.88 (0.03)	2.50 (0.12)	2.72 (3.18)	112	Included
4	255	0.86 (0.04)	2.37 (0.05)	2.35 (3.30)	112	Included
5†	204*	0.86 (0.02)	2.37 (0.08)	3.98 (2.82)	112	Included
6	248	0.99 (0.03)	2.14 (0.11)	0.80 (1.69)	125	Included
7	249	0.93 (0.03)	2.15 (0.07)	2.40 (5.01)	125	Included
8	249	0.88 (0.03)	2.16 (0.09)	4.82 (7.27)	125	Antibiotic-free
9	251	0.87 (0.03)	2.10 (0.04)	2.39 (2.79)	125	Antibiotic-free
10	249	0.96 (0.03)	2.20 (0.06)	1.61 (2.80)	125	Antibiotic-free
11	250	0.87 (0.05)	2.15 (0.07)	7.20 (5.90)	125	Antibiotic-free
12	251	0.91 (0.49)	2.11 (0.05)	3.58 (2.95)	125	Antibiotic-free
All groups	2,917	0.89 (0.05)	2.24 (0.13)	3.25 (1.79)		

* Groups 3 and 5 consisted of 80% IC barrows comingled in pens with 20% physically castrated barrows (data not shown).
† All group 5 pigs received injectable antibiotic therapy on arrival due to a confirmed diagnosis of IAV-S in the sow herd of origin, which created the possibility of viral respiratory disease complicated by bacterial infection.
IC = immunologically castrated; ADG = average daily gain; FE = feed efficiency; IAV-S = influenza A virus-swine.

Table 2: Wean-to-market performance of immunologically castrated barrows segmented by dietary regimen and compared to 2016 US swine industry benchmarks

Group	**ADG (SD), kg/day**	**FE (SD)**	**Mortality (SD), %**
2016 NPB Top 25% Producers[20]	0.79 (0.20)	2.53 (0.19)	5.53 (3.32)
2016 MetaFarms Benchmarking[21]	0.74	2.6	5.62
Groups 1-5: 112% lysine diet	0.86 (0.01)	2.36 (0.09)	3.25 (1.18)
Groups 6-12: 125% lysine diet	0.91 (0.05)	2.14 (0.03)	3.26 (2.17)
Groups 8-12: Antibiotic-free diet	0.90 (0.04)	2.14 (0.04)	3.92 (2.20)
Groups 1-12: All diets	0.89 (0.05)	2.24 (0.13)	3.25 (1.79)

ADG = average daily gain; FE = feed efficiency; NPB = National Pork Board.

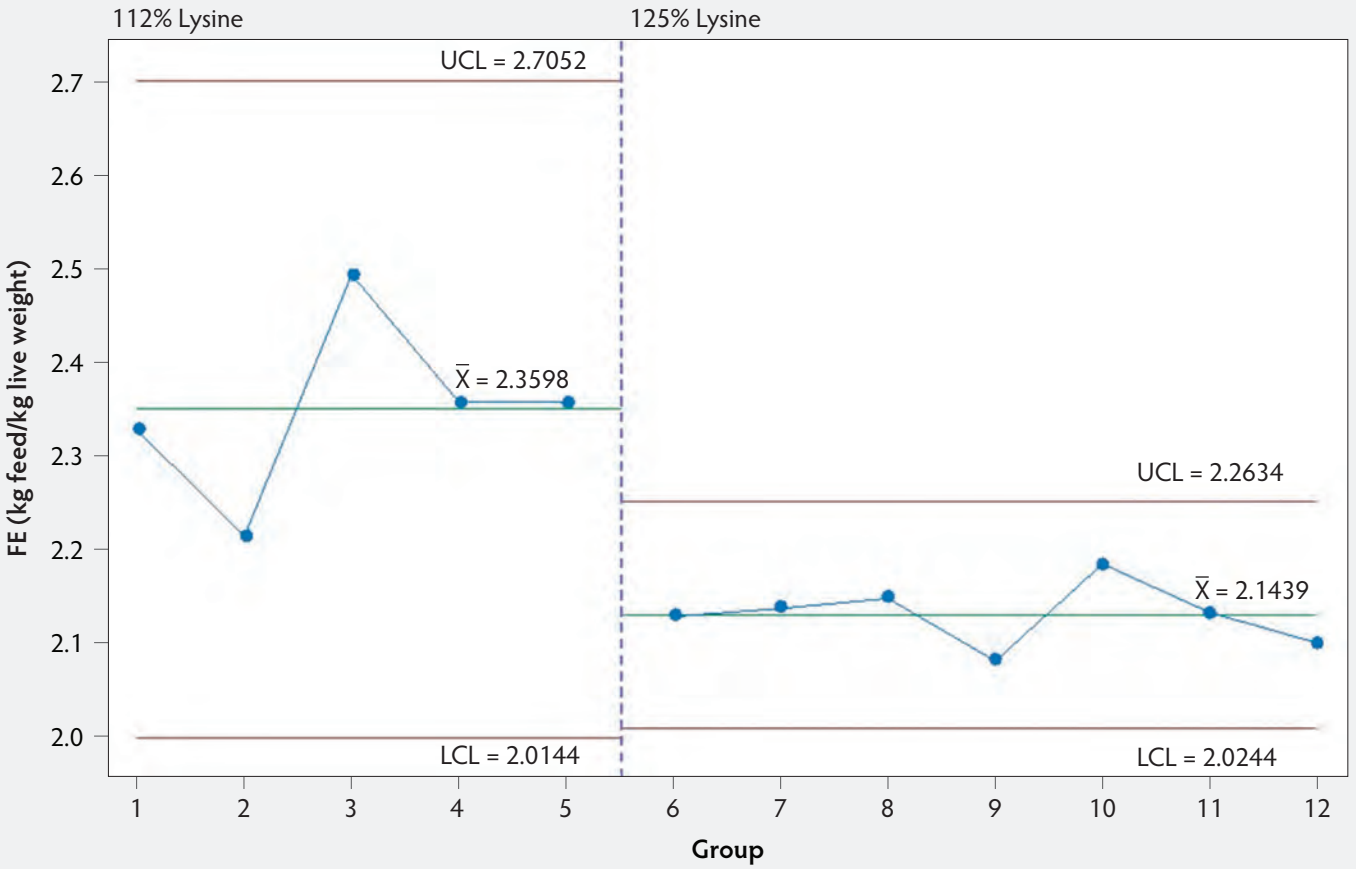
groups 6 to 12 corresponded to improved ADG and FE compared to that for groups 1 to 5. Relatively little data exists on the effect of supplementary lysine fed to intact boars. Results of our study indicate that adjusting dietary lysine is beneficial in a wean-to-finish population of intact, anti-GnRH immunized male pigs.

Individual antimicrobial treatments were followed throughout this 3.5-year study. Because the pigs were individually tagged, it was possible to determine mortality outcomes for treated and non-treated pigs in each of the 12 groups (Table 3). Nearly 3 of 4 nursery pigs that died were individually treated with injectable antibacterial agents, while only 1 of 5 finisher pigs that died were treated. This suggests that finisher pigs died from rapid onset, acute disease that occurred before it could be treated by caregivers. Absence of clinically apparent infectious disease could explain the lower treatment rate in finisher pigs compared to nursery pigs. A more aggressive approach to antibiotic therapy in response to overt clinical signs indicative of infectious disease in the finisher population may have helped reduce the death loss in this group of pigs.

As an alternative to a controlled, experimental study, the demonstration barn provided a real-world setting where variations in husbandry personnel, seasonality, diet, and antibiotic treatment existed. Even under these variable conditions, anti-GnRH immunization resulted in consistent outcomes over an extended, multi-year period.

Statistical process control is a powerful tool for analyzing the effects of management or disease control changes.[22,23] In our case, the management change was additional lysine added to rations of groups 6 to 12. The SPC chart showed improvement in FE after the

Figure 1: Feed efficiency (FE) for each of 12 groups (n = approximately 250 pigs/group) is shown. Groups 1 to 5 were fed diets with 112% lysine; groups 6 to 12 were fed diets with 125% lysine. The chart shows a distinct improvement in FE in groups 6 to 12 (mean 2.36 vs 2.26) The FE trend line remains within the UCL and LCL regardless the diet and does not indicate a sustained upward or downward trend or shift in FE in groups fed either dietary regimen. LCL = lower control limit; UCL = upper control limit; $\overline{X}$ = population mean.



diet change with reduced variation, as shown by narrowed range between the upper and lower control limits. The mean ADG was increased after the diet change and variation also increased. This change was easily observed in the SPC chart because the upper and lower control limits increased.

Anti-GnRH immunization has been commercially available for more than 20 years and is used in more than 60 swine-producing countries worldwide,[24] including extensive use in Australia and New Zealand where the concept of immunological castration originated. The adoption of immunological castration in overseas markets has been driven in part by public opposition to physical castration of pigs, particularly in the European Union, and the desire for productivity gains.[6,17,25] In contrast, anti-GnRH immunization has not been widely adopted in the United States. Survey data and expert opinion suggests that this is due in large measure to lack of consumer awareness of immunological castration and its advantages.[12,26,27] When advised of the benefits of immunological castration, consumers have consistently expressed a high level of acceptance and preference over physical castration, even if pork from IC pigs is more costly.[12,26,27] Ultimately, acceptance of a novel technology, such as immunological castration, involves the agreement of all stakeholders in the pork production chain.

Implications

Under the conditions of this study:

- IC barrows delivered consistent high performance during the 3.5 years.
- Productivity and mortality outcomes in IC pigs were unaffected by antibiotic treatments.
- Feeding IC barrows with 125% lysine diets improved ADG and FE.

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Conflict of interest

Drs Mellencamp and Galina Pantoja are employed by Zoetis. Dr Rueff was compensated by Zoetis for the use of facilities, data collection, and management of the test animals.

Disclaimer

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Figure 2: The average daily gain for each of 12 groups (n = approximately 250 pigs/group) is shown. Groups 1 to 5 were fed diets with 112% lysine; groups 6 to 12 were fed a diet with 125% lysine. The chart shows that groups 6 to 12 had a marked improvement in ADG vs groups 1 to 5 (mean, 2.01 vs 1.89 kg). The ADG trend line remains within the UCL and LCL regardless the diet and does not indicate a sustained upward or downward trend or shift in ADG in the groups fed either dietary regimen. ADG = average daily gain; LCL = lower control limit; UCL = upper control limit; $\overline{X}$ = population mean.

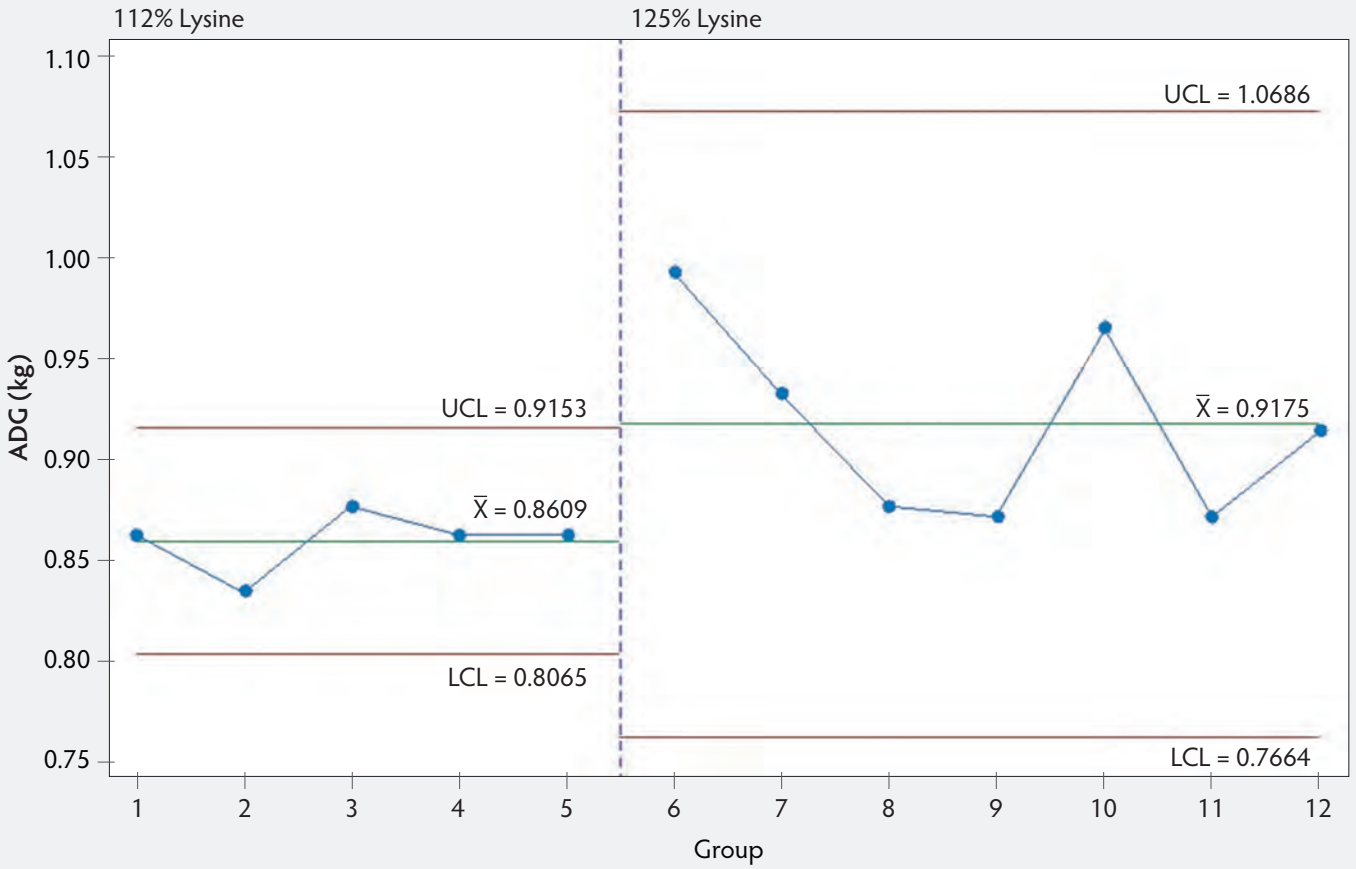

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Table 3: Injectable antimicrobial treatment rates and mortality outcomes for each group

	Nursery				Finisher			
Group	No. pigs	No. pigs treated (%)	No. dead pigs	No. dead pigs treated (%)	No. pigs	No. pigs treated (%)	No. dead pigs	No. dead pigs treated (%)
1	251	20 (7.97)	3	3 (100.00)	248	1 (0.39)	2	0 (0.00)
2	251	16 (6.37)	8	5 (62.50)	243	9 (3.58)	5	0 (0.00)
3*	255	41 (16.08)	2	2 (100.00)	253	6 (2.35)	5	0 (0.00)
4	255	16 (6.28)	3	0 (0.00)	252	3 (1.17)	3	0 (0.00)
5*	251	251 (100)	5	5 (100.00)	246	3 (1.19)	5	5 (100.00)
6	248	34 (13.71)	1	1 (100.00)	247	1 (0.40)	1	1 (100.00)
7	249	35 (14.06)	5	5 (100.00)	244	3 (1.20)	1	0 (0.00)
8	249	25 (10.04)	6	6 (100.00)	243	4 (1.61)	6	0 (0.00)
9	251	5 (1.99)	3	1 (33.33)	248	1 (0.39)	3	0 (0.00)
10	249	13 (5.22)	3	1 (22.22)	246	1 (0.40)	1	1 (100.00)
11	250	19 (7.60)	13	8 (61.53)	237	1 (0.40)	5	0 (0.00)
12	251	19 (7.57)	5	4 (80.00)	246	1 (0.39)	4	1 (25.00)
1-12	3010	494 (16.41)	57	41 (71.93)	2953	34 (1.15)	41	8 (19.51)
1-4 and 6-12†	2759	243 (8.81)	52	36 (69.23)	2707	31 (1.15)	36	3 (8.33)

* Groups 3 and 5 consisted of 80% immunologically castrated and 20% physically castrated barrows.

† To accurately represent the usual mortality and treatments on this farm, group 5 was excluded because 100% of the pigs received injectable antibiotic therapy on arrival due to a confirmed diagnosis of influenza A virus-swine in the sow herd of origin, which created the possibility of viral respiratory disease complicated by bacterial infection.

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