Original research

Peer reviewed

Seroprevalence of *Lawsonia intracellularis* in Ontario swine herds

Cesar A. Corzo, DVM, MSc; Robert M. Friendship, DVM, MSc, Diplomate ABVP; Cate E. Dewey, DVM, MSc, PhD; Tim Blackwell, DVM, MSc, PhD

Summary

Objective: To estimate the seroprevalence of *Lawsonia intracellularis* in finisher pigs and sows in the province of Ontario.

Methods: Serum samples from a total of 1061 pigs in 37 Ontario commercial herds were collected and tested using the indirect immunofluorescent antibody test. Differences in within-herd prevalence for type of herd, continuous flow or all-in, all-out management in the finishing barn, and inclusion of in-feed antibiotics were examined.

Results: Seroprevalence of *L intracellularis* was 90% for sows and 56% for finisher pigs. Seventy-three percent of herds were seropositive. Within-herd prevalence was higher in farrow-to-finish farms than in multi-site operations ($P < .001$), and lower in herds with all-in, all-out rather than continuous-flow management in the finishing barn ($P < .01$).

Implications: Under the conditions of this study, seroprevalence of *L intracellularis* was high, suggesting that the organism is widespread in the Ontario swine population. More sows than finisher pigs are seropositive. Serologic tests are valuable tools for determining the status of the herd with respect to *L intracellularis* infection.

Keywords: swine, porcine proliferative enteropathy, serology, indirect immunofluorescent antibody test

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Resumen – Seroprevalencia de *Lawsonia intracellularis* en las piaras de cerdos en Ontario

Objetivos: Estimar la seroprevalencia de *Lawsonia intracellularis* en cerdos de finalización y hembras en la provincia de Ontario.

Métodos: Se obtuvieron muestras de suero de un total de 1061 cerdos de 37 piaras comerciales de Ontario y se probaron utilizando la prueba de inmunofluorescencia indirecta para detección de anticuerpos.

Se analizaron las diferencias de prevalencia dentro de piara dependiendo del tipo de granja, flujo continuo ó todo dentro-todo fuera en la finalización y la inclusión de antibióticos en alimento.

Resultados: La seroprevalencia de *L intracellularis* fue del 90% para las hembras y de 56% para los cerdos de finalización. El setenta y tres por ciento de las piaras fueron seropositivas. La prevalencia dentro de piara fue más alta en las granjas de ciclo completo que en las operaciones de sitios múltiples ($P < .001$) y fue menor en las piaras con manejo todo dentro-todo fuera que en las de flujo continuo en la finalización. ($P < .01$).

Implicaciones: Bajo las condiciones de este estudio, la seroprevalencia de *L intracellularis* fue alta, lo que sugiere que el organismo está diseminado en la población porcina de Ontario. Existen más hembras seropositivas que cerdos de finalización. Las pruebas serológicas son una herramienta valiosa para determinar el estatus de la piara con respecto a la infección del *L intracellularis*.

Resumé - Séroprévalence de *Lawsonia intracellularis* dans les troupeaux porcins d'Ontario

Objectifs: Estimer la séroprévalence de *Lawsonia intracellularis* dans truies et porcs de finition en la province d'Ontario.

Méthodes: Les échantillons de sérum d'un total de 1061 cochons de 37 troupeaux commerciaux à Ontario ont été collectée et testé avec l'épreuve de immunofluorescence indirecte pour la détection des anticorps.

Les différences de prévalence entre le troupeau pour type de troupeau, naisseur-finisseur ou tout pleine tout vide à la finition, et l'inclusion d'antibiotiques dans l'alimentation ont été examinés.

Résultats: La séroprévalence de *L intracellularis* a été de 90% pour les truies et 56% pour les porcs de finition. Le soixante-treize pour cent des troupeaux ont été séropositifs. La prévalence entre le troupeau a été plus haute dans les troupeaux naisseur-finisseur que dans les opérations multi-site ($P < .001$), et inférieur dans les troupeaux tout pleine tout vide plutôt que le flux continu à le finisseur ($P < .01$).

Implications: Sous les conditions de cette étude, la seroprevalence de *L intracellularis* a été haut, en suggérant que l'organisme s'a propagé dans la population porcine d'Ontario. Plus de truies sont séropositives que de porcs de finition. Les épreuves sero-logic sont des outils essentiels pour déterminer le statut du troupeau en ce qui concerne l'infection de *L intracellularis*.

CAC, RMF, CED: Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario.

TB: Ontario Ministry of Agriculture and Food, Fergus, Ontario.

Corresponding author: Dr Robert Friendship, Department of Population Medicine, University of Guelph, Guelph, Ontario, Canada N1G 2W1; Tel: 519-824-4120, Ext 54022; Fax: 519-763-3117; E-mail: `rfriends@uoguelph.ca`.

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P orcine proliferative enteropathy (PPE) is an important infectious disease of swine reported in many countries around the world and affecting pigs of various ages. The causative agent, *Lawsonia intracellularis,* produces two clinical syndromes in pigs. Proliferative hemorrhagic enteropathy is an acute hemorrhagic disease, generally occurring in the late grower-finisher stage or affecting replacement breeding stock. Porcine intestinal adenomatosis is a chronic and often mild disease, generally affecting young grower pigs, and is associated with increased weight variation among groups and delayed time to market.[1]

Serologic tests are often used to detect infection with *L intracellularis*, as the nonspecific clinical signs[2] make antemortem diagnosis very challenging. In addition, gross lesions observed at slaughter or necropsy may not be wholly reliable as a means of detecting *L intracellularis* or determining the extent of clinical disease within a population. Mild lesions may go unnoticed. Moreover, lesions may heal, preventing identification of recovered animals.[3,4]

Canadian studies based on a review of records of submissions of pigs to provincial diagnostic laboratories for necropsy examination reveal that in both Alberta[5] and Ontario,[6] *L intracellularis* is one of the most frequently diagnosed causes of enteric disease in grower-finisher pigs. However, the actual prevalence of *L intracellularis* and clinical cases of PPE in the general population of pigs remains unknown because extensive random testing has not been performed. The objective of our study was to estimate the seroprevalence of *L intracellularis* in commercial swine herds in the province of Ontario.

Materials and methods

A total of 37 herds were randomly selected from a list of all Ontario pork producers, stratified on farm size, production type, and geographical distribution. This allowed us to obtain a sample that included different types of herds of different sizes and from different locations in the province. Sample-size calculations[7] were performed to determine the number of pigs to be serologically tested for *L intracellularis* in order for a 20% prevalence to be detected with 95% confidence. For group sizes of 200, 500, and 800 finisher pigs, sample sizes of 13, 13.2, and 13.6 pigs, respectively, were estimated

to be sufficient. On this basis, it was decided to obtain 15 blood samples from groups of finishers and 15 samples from sows on farms where both finishers and sows were present. Thirty samples were collected in herds that included only grower-finisher pigs or only sows. Finisher pigs were tested at 20 to 24 weeks of age.

A face-to-face survey was completed at the time of the farm visit to collect information on herd size (number of finisher pigs in the barn), all-in, all-out management, and use of in-feed antibiotics.

A total of 1061 samples from 613 finisher pigs and 448 sows were tested from 22 herds that included both sows and finisher pigs, 11 herds with only finisher pigs, and four herds with only sows.

Serologic testing

Samples were tested using the indirect immunofluorescent antibody test (IFAT)[8] for detection of *L intracellularis*-specific antibodies, with slight modifications. Briefly, pure cultures of *L intracellularis* were fixed in 15-well glass slides. Serum samples were diluted 1:30 in phosphate buffered saline (PBS; pH 7.2), and 5 µL of diluted serum was added to each well. Slides were stored for 12 hours in a humidified chamber at 4°C, then washed eight times with PBS. The first wash was performed by rapidly rinsing the slide, and subsequent washes by placing the slide in a petri dish containing PBS, with constant agitation for 5 minutes, using fresh PBS for each wash. The slides were allowed to dry, then 5 µL of anti-porcine IgG-fluorescein-isothiocyanate conjugate was added to each well. After addition of the conjugate, all steps were performed in a dark environment. Slides were incubated for 45 minutes at 37°C in a humidified chamber, then washed as described, except that distilled water was used in the final wash. After drying, slides were examined under a fluorescent microscope: observation of fluorescing bacteria classified the serum as positive. The sensitivity and specificity of this test were assumed to be the same as for the original IFAT, ie, sensitivity (the probability that a test applied to a diseased pig is positive) was assumed to be 91% and specificity (the probability that a test applied to a disease-free pig is negative) was assumed to be 97%.

Analysis of data

Data were analyzed using STATA (Stata Statistical Software, Release 8.0; Stata Corporation, College Station, Texas). Differences in seroprevalence between herds with different management systems (continuous flow or all-in, all-out) and types of production systems (farrow-to-finish or grower-finishers only) were tested by the Mann-Whitney *U* test. Correlation between breeding-herd and finisher-herd prevalence was tested using Spearman's rank correlation coefficient. Each herd was classified as either positive or negative according to the number of reactors.[9] The cut-point was calculated using a program for calculating herd-level sensitivity and specificity.[10] On the basis of this procedure, herds with fewer than three positive reactors among 15 pigs sampled were classified as negative, and herds with three or more positive reactors among 15 pigs sampled were classified as positive. Herd sensitivity (99.9%) and specificity (99.1%) were highest when this cut-point was used to classify herds.

Due to the nature of the test results (positive or negative), multivariate logistic regression was performed to investigate the association between risk factors and our outcome (seropositivity). Herd was included in the model as a random effect to account for clustering within the herd. All predictors were forced in the model, and subsequent backward elimination was performed. Herd size was measured in 250-pig increments. The final model was assessed using the Hosmer-Lemeshow (H-L) goodness-of-fit test. As this test does not allow random variables in the model, herd was not included as a random variable.

Results

Of the 1061 animals sampled, 404 of 448 sows (90%) and 343 of 613 finisher pigs (56%) tested positive. There was no correlation between prevalence in the breeding and finishing herds (rho = 0.13; *P* = .5).

All sow herds were classified positive, and 20 of 22 of their respective finishing herds were classified positive. Of the 33 herds where finisher pigs were tested, 24 (72.7%) had at least three positive pigs, ie, were classified positive. Mean within-herd prevalence was 62.3% for the 33 herds with finisher pigs and 83.4% for the 24 of these herds that were classified positive.

Parity of sows ranged from zero to over eight, with at least 13 sows in each parity. Seroprevalence in sows did not differ by parity and ranged from 86% to 100%.

Within-herd prevalence was higher ($P < .001$) in farrow-to-finish herds (78.5%) than in herds with only finisher pigs (25%). Within-herd prevalence was higher ($P < .01$) in herds with continuous-flow management in the finishing barn (76%) than in herds with all-in, all-out management (19.5%). Within-herd prevalence was numerically lower in the 16 herds that included in-feed antibiotics in the finisher ration (56.8%) than in herds that did not use in-feed antibiotics (67.5%). In the eight herds that used tylosin in the finishing ration, 104 of the 135 finisher pigs tested were seropositive (77%), whereas in the five herds that used both tylosin and lincomycin in the finishing ration, 22 of the 135 finisher pigs tested were seropositive (16.3%). In the two herds that used bacitracin in the finishing ration, 15 of the 45 pigs tested were seropositive (33.3%). In the single herd that used lincomycin in the finishing ration, all 15 finisher pigs tested were seropositive.

The final multivariate model (Table 1) excluded the farrow-to-finish variable because it was highly correlated with continuous flow (Pearson correlation coefficient = 0.80) and distorted the estimates of the odds ratios. Most herds with continuous-flow management in the finishing barn were farrow-to-finish herds. Herds managed by continuous flow were 23 times more likely to have seropositive pigs than herds with all-in, all-out management. When in-feed antibiotics were used in the finishing ration, herds were less likely to have seropositive pigs. The odds of a pig being seropositive increased as herd size increased by 250 finisher pigs. The H-L goodness-of-fit test suggested that the model did not fit the data very well (H-L χ^2 [8 df] = 78.92, $P < .001$).

Discussion

The results of this study indicate that *L intracellularis* is widespread in the Ontario swine population, with antibodies detectable in nearly 75% of the herds tested in this study. The 90% seroprevalence in sows, regardless of parity, suggests that *L intracellularis* antibodies are more common in sows than in finisher pigs (seroprevalence 56%). The

Table 1: Logistic regression model for individual *L intracellularis*-seropositive status of 613 finisher pigs from 33 herds[1]

Risk factor	Odds ratio	P	95% confidence interval
Continuous flow	22.61	< .001	10.73 - 47.61
In-feed antibiotics	0.51	.07	0.24 - 1.05
Finisher herd size[2]	1.24	< .001	1.10 - 1.40

1   Blood samples were collected from finisher pigs (20 to 24 weeks of age) in commercial herds in Ontario, Canada, and tested using the indirect immunofluorescence antibody test. The model included herd as a random effect.

2   The odds of seropositivity if finisher herd size is increased by 250 pigs.

high seroprevalence in sows may be due to repeated exposure to *L intracellularis,* which would maintain antibodies at detectable levels. Loose sow housing plus floor-feeding management practices may contribute to maintaining high *L intracellularis* antibody levels, since contact with feces of pen-mates is very likely. Another explanation for the high seroprevalence in adult pigs might be that older animals are likely to be exposed to a greater number of microorganisms over their life spans and therefore are more likely than relatively naive young animals to possess antibodies that might cause cross-reactivity with *L intracellularis*. No cross reactions were reported[8] in young pigs tested with the IFAT; however, in our study, adult pigs were tested, and a slightly different IFAT test, that might have caused nonspecific reactions, was used. This possibility should be investigated.

In this study, *L intracellularis* antibodies were detected in more than half of the finisher pigs tested. Similar results were found in a Korean study[11] in which pigs from five provinces were tested with the IFAT. The proportion of positive pigs per province ranged from 43.9% to 68.6%, with an overall prevalence of 56.4%. Interestingly, *L intracellularis* seroprevalence was similar in wild pigs tested in the Czech Republic.[12]

No correlation was found between breeding-herd and finishing-herd seroprevalence. However, the Czech study[12] may not have had the power to measure this association, because all breeding herds and almost all finishing herds (91%) were classified as positive. In an earlier study comparing the serological status of 123 breeding and finishing herds, the status of the breeding herd was associated with the status of the finishing herd.[13] Even though the means

by which *L intracellularis* is transmitted within a herd has not been fully studied, we believe that sows might represent a very important source of *L intracellularis* via fecal transmission to their offspring and from them to commingled pigs. Among 22 herds included when correlation between breeding-herd and finisher-herd prevalence was tested, finishing and breeding herds were housed at different sites in only four cases, and only one of these four finishing herds was classified as negative. The other negative finishing herd was on the same site as the breeding herd, but tylosin included in the finisher ration at 22 g per tonne might have prevented these pigs from developing a detectable immune response. From this study, it is not clear whether the number of production sites in a system affects the *L intracellularis* serological status of breeding and finishing herds. Breeding and finishing herds are more likely to both be positive in one-site operations because of the possibility of transmitting the organism from one group to another via carrier pigs, personnel, rodents, or fomites that move between the breeding and finishing areas. This is also likely the reason for the higher within-herd prevalence in farrow-to-finish herds compared to finishing herds.

In finishing herds stocked with feeder pigs from different sources, antibiotics are likely to be included in the feed for incoming groups as a prophylactic measure, as outbreaks of disease may occur when pigs of different immune status are commingled. It has been suggested that antibiotics may prevent infection with *L intracellularis*[14] and antibodies are not produced, so that these pigs test seronegative. Our results corroborate this: pigs in herds using in-feed medication were less likely to be seropositive.

In this study, pigs housed in barns with continuous-flow management were more likely to be seropositive than pigs managed in all-in, all-out facilities. Continuous-flow management in finishing barns has disadvantages, compared to all-in, all-out management.[15] There is a build-up of pathogens in the building when it is not completely cleaned, exposing the next group of pigs to a high concentration of pathogens that might include *L intracellularis*. Our results agree with those of other studies,[16,17] that all-in, all-out management reduces the incidence of disease. In this study, the number of seropositive pigs was lower when all-in, all-out management was used, suggesting that the probability of exposure was lower. It is likely that on farms with all-in, all-out management, cleaning protocols are better, which tends to reduce the survivability of microorganisms. It has been suggested that strict sanitation protocols, such as cleaning, disinfection, and drying, are very important for disease control and prevention.[18] If the cleaning protocol includes washing with hot water and use of disinfectants such as quaternary ammonium or iodine-based compounds,[19] the bacterial challenge from *L intracellularis* will be decreased.

Bane et al[20] found a relationship between the number of growing pigs in the herd (ie, herd size) and clinical disease, which agrees with our findings, ie, an increase in the number of finishing pigs increased the odds of a pig testing positive or being exposed to *L intracellularis*. In the study of Bane et al,[20] the occurrence of clinical signs and histologic findings, rather than seropositivity, was the outcome measured.

We are aware that the overall fit of the model was not significant, which may be associated with the small sample size, failure to include herd in the model when the goodness-of-fit test was conducted, or both. However, we do believe that the model provides useful information.

It is important to mention that the *L intracellularis* avirulent live-culture vaccine was not available in Canada when these samples were collected. Therefore, in this study, antibodies induced by vaccination[21] were not a confounding factor. In future studies in Ontario, antibodies produced in response to vaccination will have to be taken into account. This study suggests that *L intracellularis* is widespread in the swine population in Ontario, but the existing serologically negative herds will have to be cautious when introducing replacement pigs to avoid outbreaks of PPE.

Implications

- *Lawsonia intracellularis* infection is endemic in the province of Ontario, with almost 75% of herds having detectable levels of antibodies.
- *Lawsonia intracellularis* antibodies are more prevalent in sows than in finishing pigs.
- Under the conditions of this study, within-herd seroprevalence of *L intracellularis* is higher in farrow-to-finish farms than in multi-site operations, and in finishing barns with continuous-flow management compared to all-in, all-out management.
- The IFAT test interpreted at herd level is a good tool for determining *L intracellularis* herd status.

Acknowledgments

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Original research

Effects of ractopamine HCl on growth performance and within-pen weight variation in finishing pigs

Matt R. Barker, MS; Steve S. Dritz, DVM, PhD; Mike D. Tokach, PhD; Robert D. Goodband, PhD; Crystal N. Grosebeck, MS

Summary

Objective: To determine if ractopamine HCl added to finishing pig diets during the final 21 days to market affects within-pen variation and growth performance.

Methods: A total of 336 pigs (12 pigs per pen, 14 pens per treatment) were weighed and assigned to treatment groups (diets with or without ractopamine) in a randomized complete block design so that, within gender, mean weight and degree of weight variation were the same in each pen. Diets were based on sorghum and soybean meal and formulated to contain 1.00% total

lysine, with or without 10 mg per kg of ractopamine HCl. Pigs were weighed and feed intake was measured every 7 days during the 21-day experiment to determine average daily gain (ADG), average daily feed intake (ADFI), feed efficiency (G:F), and pen coefficient of weight variation (CV).

Results: In pigs fed ractopamine HCl, compared to control pigs, ADG was greater, G:F was better, and final weight was greater at the end of the 21-day trial, but ADFI and CV did not differ between dietary treatments.

Implications: These findings suggest that, under the conditions of this study, ractopamine supplementation results in better growth performance and feed efficiency. The greater gain associated with ractopamine supplementation affects all pigs proportionally, with no impact on final weight variation within a pen.

Keywords: swine, finishing pigs, growth, ractopamine, coefficient of weight variation

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Resumen - Efectos del HCl de ractopamina en el desempeño del crecimiento y la variación del peso dentro de corral en cerdos de finalización

Objetivo: Determinar si agregar HCl de ractopamina a la dieta de cerdos en finalización durante los últimos 21 días antes de la venta afecta el desempeño del crecimiento y la variación dentro del corral.

Métodos: Un total de 336 cerdos (12 cerdos por corral, 14 corrales por tratamiento) se pesaron y se asignaron a grupos de tratamiento (dietas con o sin ractopamina) en un diseño al azar de bloque completo de manera que, el sexo, peso promedio y grado de variación de peso fueran los mismos dentro de cada corral. Las dietas se basaron en sorgo y harina de soya y fueron formuladas para contener 1.00% total de lisina, con ó sin 10 mg por kg de HCl de ractopamina. Se pesaron los cerdos y se midió el consumo de alimento cada 7 días durante los 21 días del experimento, para determinar la ganancia

diaria promedio (ADG por sus siglas en inglés), el consumo diario promedio de alimento (ADFI por sus siglas en inglés), la eficiencia alimenticia (G:F por sus siglas en inglés) y el coeficiente de variación de peso por corral (CV por sus siglas en inglés).

Resultados: En los cerdos alimentados con HCl de ractopamina, comparados con los cerdos control, la ADG fue mayor, la G:F fue mejor, y el peso final fue mayor al final de los 21 días de prueba, pero el ADFI y el CV no difirieron entre los tratamientos dietéticos.

Implicaciones: Estos hallazgos sugieren que, bajo las condiciones de este estudio, el suplemento con ractopamina resulta en un mejor desempeño del crecimiento y eficiencia alimenticia. La mayor ganancia asociada con el suplemento de ractopamina afecta a todos los cerdos de manera proporcional, sin tener un impacto en la variación final del peso dentro de un mismo corral.

Résumé - Effets du HCl de ractopamine sur la performance de la croissance et la variation du poids en les parcs de cochons de finition

Objectif : Déterminer si le HCl de ractopamine qui a été ajouté a la moulée du cochon de finition pendant les 21 jours avant la vente affecte la variation en les parcs et la croissance.

Méthodes: Un total de 336 cochons (12 cochons par parc, 14 parcs par traitement) a été pesé et assigné aux groupes du traitement (moulée avec ou sans ractopamine) dans un dessin randomisé du bloc complet afin que le genre, poids moyen et degré de variation du poids étaient les mêmes dans chaque parcs. La moulée ont été basées sur sorgho et farine de soja et ont été formulées pour contenir 1.00% de lysine totaux, avec ou sans 10 mg par kg de HCl de ractopamine. Les cochons ont été pesés et la ration a été mesurée chaque 7 jours pendant les 21 jours de l'expérience pour déterminer la gain journalier moyen (ADG par ses sigles en anglais), la consumation de aliment journalier moyenne (ADFI para ses sigles en anglais), l'efficacité de l'alimentation (G:F par ses sigles en anglais), et le coefficient de la variation du poids (CV para ses sigles en anglais) entre le parc.

Résultats: Dans les cochons qui ont été nourris avec le HCl de ractopamine, comparé a les cochons contrôle, le ADG a

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MRB, MDT, RDG, CNG: Department of Animal Sciences and Industry, Kansas State University, Manhattan, Kansas.

SSD: Food Animal Health and Management Center, College of Veterinary Medicine, Kansas State University, Manhattan, Kansas.

Corresponding author: Dr R. D. Goodband, Kansas State University, 242 Weber Hall, Manhattan, KS 66506; Tel: 785-532-1228; Fax: 785-532-7059; E-mail: Goodband@ksu.edu.

été plus grand, le G:F a été meilleur, et le poids final a été plus grand à la fin du 21 jours, mais le ADFI et le CV n'ont pas différés entre les traitements.

Implications: Ces résultats suggèrent que, sous les conditions de cette étude, la supplémentation du ractopamine résulte en une meilleure performance de la croissance et l'efficacité alimentaire. Le plus grande augmentation associée avec la supplémentation du ractopamine affecte tous les cochons proportionnellement, sans impact sur la variation du poids en un parc.

Swine producers are continually looking for methods to reduce the number of lightweight pigs at marketing. Lightweight pigs in all-in, all-out (AIAO) facilities either incur packer penalties or increase cost of production by necessitating use of the facility to provide more time for the lightweight pigs to gain weight.[1] Reducing body weight variation would result in fewer lightweight pigs at market. Sorting pigs into uniform body-weight groups is thought to reduce the number of lightweight pigs at marketing by reducing body weight variation. However, sorting pigs into pens of similar size had no effect on final variation of individual body weights, and not sorting by weight may actually increase overall pork produced and reduce turnaround time within the barn.[2] Ractopamine HCl (Paylean; Elanco, Indianapolis, Indiana), a β–adrenergic agonist, is an effective growth promotant in swine. Ractopamine HCl supplementation increases average daily gain, improves feed conversion, and increases dressing percentage.[3–5] Additionally, field observations suggested that body weight variation was reduced when pigs were fed ractopamine. Therefore, our objective was to determine if ractopamine HCl supplementation during the final 21 days before market would affect within-pen weight variation and growth performance of finishing pigs.

Materials and methods

Animals and housing
Experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee. The experiment was divided into two trials conducted in May and July of 2002 at the Kansas State University Swine Teaching and Research Center. A total of 336

finishing pigs (PIC L327 × 1050 genetics; 168 barrows and 168 gilts), initially weighing 110.5 kg ± 2.2 kg, were housed 12 per pen in 28 pens, allowing 0.74 m² space per pig. Pigs were free of clinical signs of enteric or respiratory disease for the 2 weeks prior to the trials.

Pigs were housed in a modified open-front finishing barn with partially-slatted pens (1.8 m × 4.9 m; 50% slatted), operated AIAO by group. Each pen contained a single nipple waterer and a two-hole self-feeder to allow ad libitum access to water and feed. Diets were based on sorghum and soybean meal and formulated to contain 1.00% total lysine, with or without 10 mg per kg of ractopamine HCl (Table 1).

Experimental Design
Pens were randomly assigned to one of two treatments (Control or Ractopamine) in a randomized complete block design with trial and gender as blocking factors. Each treatment consisted of 14 replicates (pens), with seven replicates per gender (four in Trial 1 and three in Trial 2). Individual pigs within gender and trial were then randomly assigned to pens so that mean weight and coefficient of body weight variation did not differ across treatment.

Response criteria
At 7-day intervals during the 21-day experiment, pigs were weighed individually and feed intake was measured for determination of average daily gain (ADG), average daily feed intake (ADFI), feed efficiency (gain-to-feed ratio: G:F), and pen coefficient of weight variation (CV). The CV was determined by dividing the standard deviation of pig weights in the pen by the mean weight of the pigs in that pen.

Statistical analysis
Treatment differences were evaluated using an analysis of variance mixed model for a randomized complete block design with the fixed effect of treatment and random effects of gender and trial.[6] Pen was the experimental unit for the analysis of variance. Data were analyzed using the Proc Mixed procedure of SAS version 8.1 (SAS Institute, Cary, North Carolina).

A secondary analysis was performed using pig as the experimental unit. For this analysis, a frequency distribution histogram of individual pig weights by either Control or Ractopamine treatment was first developed, then the association between initial pig weight and subsequent ADG over the 21-day experiment was examined using the

Table 1: Composition of diet (as-fed) for 336 finishing pigs in a 21-day trial*

Ingredient	% of diet
Sorghum	74.03
Soybean meal (46.5% crude protein)	23.82
Monocalcium phosphate (21% phosphorus)	0.55
Calcium carbonate	0.90
Sodium chloride	0.35
Vitamin premix†	0.10
Trace mineral premix‡	0.10
Lysine HCl	0.15
Total	**100.00**
Calculated analysis	
Metabolizable energy (Mcal/kg)	3.28
Lysine (%)	1.00
Calcium (%)	0.55
Phosphorus (%)	0.49

* Equal numbers of pigs were fed the base diet with or without ractopamine (Paylean; Elanco, Indianapolis, Indiana) added at 0.05% (providing 10 mg/kg ractopamine HCl).

† Provided per kg of complete diet: vitamin A, 4409 IU; vitamin D₃, 661 IU; vitamin E, 18 IU; vitamin K, 1.8 mg; vitamin B₁₂, 0.02 mg; riboflavin, 3.3 mg; pantothenic acid, 11 mg; and niacin, 20 mg.

‡ Provided per kg of complete diet: manganese, 27 mg; iron, 110 mg; zinc, 110 mg; copper, 11 mg; iodine, 0.2 mg; and selenium, 0.2 mg.

Proc Mixed procedure of SAS to develop two regression models. The first model contained the fixed effects of treatment, initial weight as a covariate, the treatment-by-initial-weight interaction term, and the random effects of gender and trial. The second model was the same without the interaction term.

Results

Pigs were free of clinical signs of enteric or respiratory disease during the trials. The Ractopamine pigs had greater ADG ($P < .01$) and better feed efficiency than the Control pigs; however, ADFI was not affected by dietary treatment (Table 2). As a result of the greater ADG, final weight was heavier for the Ractopamine pigs. Pen CV decreased between the start and the finish of the 21-day trial for both the Control and Ractopamine pigs, and neither starting nor final CV differed between dietary treatments ($P > .05$). Average pen CV for Control pigs was 3.5%: thus, 68% of these pigs weighed between 112.3 and 120.5 kg, a range of 8.2 kg. Average pen CV for Ractopamine pigs was 3.7%: thus 68% of these pigs weighed between 115.5 and 124.3 kg, a range of 8.9 kg.

The secondary analysis of the frequency distribution of final weights showed that the distribution was shifted to the right for the Ractopamine pigs (Figure 1). In the first regression model, the initial weight-by-interaction term was not significant ($P = .81$). In the second regression model, there was no evidence of an effect of initial weight on ADG, ie, the slope of the relationship did not differ from zero ($P = .27$). However, the intercepts of the relationship were different ($P < .01$) because AGD was higher for the Ractopamine pigs compared to the Control pigs (Figure 2).

Discussion

Ractopamine HCl, a phenethanolamine, alters the manner in which nutrients are directed toward fat deposition and muscle accretion. Adipose tissue is reduced through a decrease in lipogenesis, and protein accretion is increased.[7] The 16% higher ADG in the Ractopamine pigs in this study is consistent with results of recent research.[4,8,9] Studies on ractopamine supplementation of finishing diets have shown either no effect on feed intake or a decrease in feed intake,[3,5,10] in agreement with the present study, and the 16% higher G:F in the Ractopamine pigs in this study

is also in agreement with previous results.[3,11]

The lack of a significant interaction term in the regression analysis of initial weight and subsequent ADG suggests that there is no evidence that the relationship between initial weight and subsequent ADG was different in Control and Ractopamine pigs.

Thus, on the basis of the results of this experiment, we believe that the reduction in number of lightweight pigs that is associated with ractopamine HCl supplementation, from our field observations, is a result of a shift to the right of the weights of the whole population of pigs. If the smaller

Table 2: Growth performance and weight variation in 336 finishing pigs fed either a diet containing ractopamine or a control diet for 21 days*

Production variable	Control	Ractopamine	SEM	P†
Initial weight (kg)	100.3	100.8	2.25	.62
Initial weight CV (%)	4.2	3.9	0.27	.52
ADG (kg/day)	0.80	0.94	0.07	.01
ADFI (kg/day)	2.76	2.77	0.17	.96
G:F	0.31	0.36	0.01	.01
Final weight (kg)	116.4	119.9	2.35	.02
Final weight CV (%)	3.5	3.7	0.19	.42

* Equal numbers of pigs were fed the control sorghum-soybean diet or the same diet containing ractopamine (10 mg/kg). At 7-day intervals during the trial, feed intake was measured and all pigs were weighed individually. Two trials were conducted, with four replicates per gender in Trial 1 and three in Trial 2. Values represent the least squares means for 14 pens (replicates) per treatment, with seven pens of barrows, seven pens of gilts, and 12 pigs per pen. Average daily gain (ADG) was calculated as pen weight gain ÷ total pig days; average daily feed intake (ADFI) was calculated as pen feed intake ÷ total pig days; feed efficiency (G:F) was calculated as individual pen ADG ÷ individual pen ADFI; and pen coefficient of weight variation (CV) was calculated as within-pen weight standard deviation ÷ pen mean average pig weight.

† A mixed model analysis of variance was used to determine statistical significance, with treatment a fixed effect and gender and trial as random effects.

Figure 1: Frequency distribution of final weights for treatment groups of pigs fed the same diet either with 10 mg/kg ractopamine HCl (Ractopamine) or without ractopamine (Control). A total of 336 pigs (96 barrows and 96 gilts in Trial 1 and 72 barrows and 72 gilts in Trial 2) were fed for 21 days prior to obtaining the final weight.
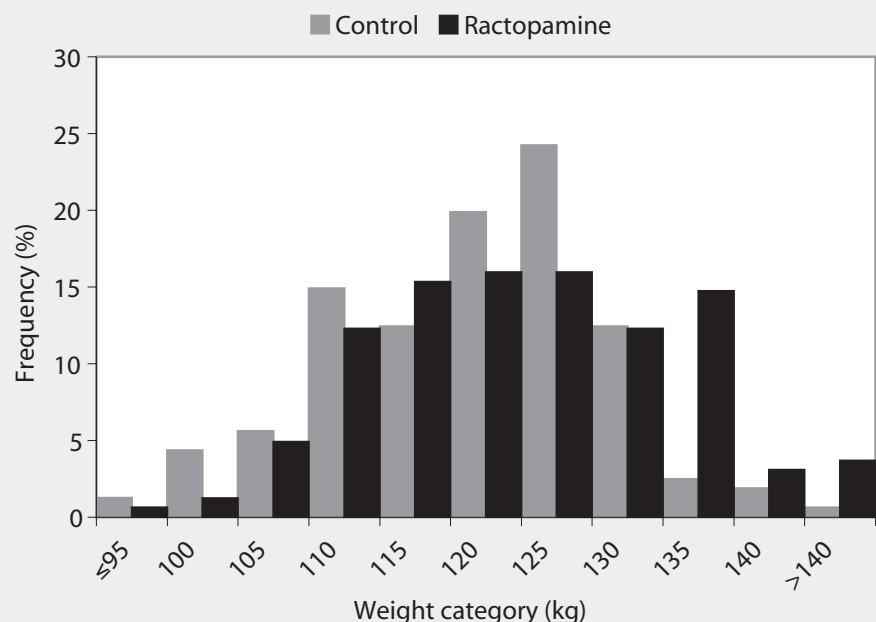
Figure 2: Regression analysis of initial weight and subsequent average daily gain (ADG) for pigs fed the same diet either with 10 mg/kg ractopamine HCl (Ractopamine) or without ractopamine (Control). A total of 336 pigs (96 barrows and 96 gilts in Trial 1 and 72 barrows and 72 gilts in Trial 2) were fed for 21 days. The regression model contained the fixed effects of treatment, initial weight as a covariate, and the random effects of gender and trial. There was no evidence for a relationship between initial weight and ADG, ie, there was no evidence ($P = .27$) that the slope of the relationship was different from zero. The regression equations were ADG (kg) = -0.00131 × initial weight (kg) + 0.9264 (Control pigs) and ADG (kg) = -0.00131 × initial weight (kg) + 1.0824 (Ractopamine pigs).
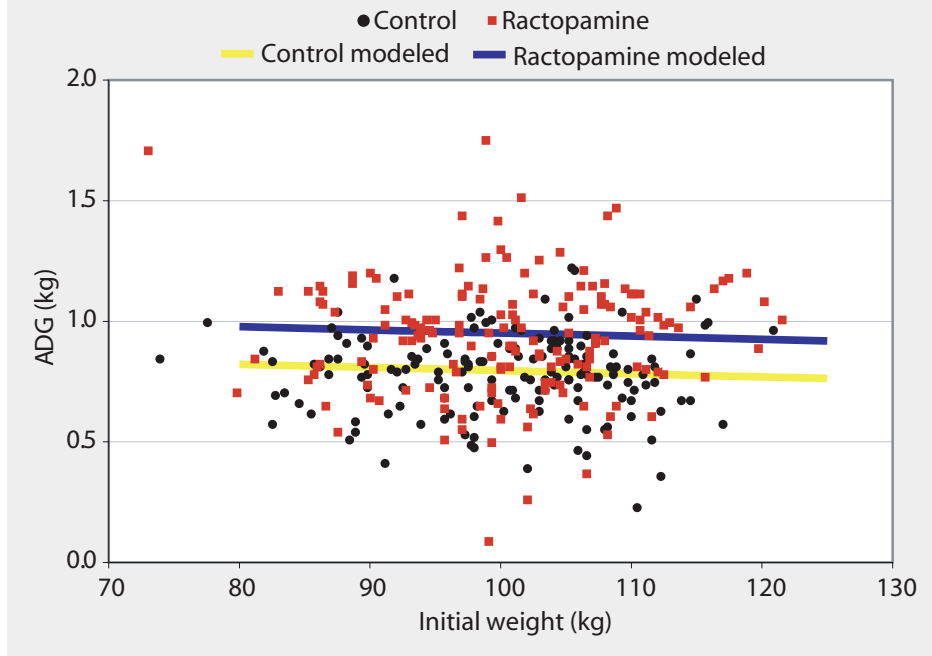
number of lightweight pigs had been due to a smaller weight variation, we would have expected to observe a significantly lower within-pen CV in the Ractopamine pigs. Further support is provided by the lack of interaction between treatment and initial weight and lack of influence of initial weight on subsequent ADG. In order for a smaller CV to be responsible for the smaller number of lightweight pigs, we would expect lightweight Ractopamine pigs to have had a higher ADG than lightweight Control pigs. The lack of association or interaction indicates that this is not the case.

Implications

- Under the conditions of this study, ractopamine HCl supplementation for 21 days before marketing finisher pigs results in better gain and feed efficiency.
- The greater gain associated with ractopamine supplementation affects all pigs proportionally, with no impact on final weight variation within a pen.

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