Effects of different antibiotic feeding programs on morbidity and mortality and growth performance of nursery pigs housed in a wean-to-finish facility

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ABSTRACT: The objective of this study was to evaluate the effects of two antibiotic feeding programs in comparison to nonmedicated controls on the incidence of morbidity and mortality and growth performance of nursery pigs in a commercial setting. The study used 2,250 crossbred pigs in a randomized complete block design (blocking factor = start date). There were two dietary phases with three treatments in each phase: 1) nonmedicated controls vs. 2) 39 mg/kg (35 g/ton) tiamulin + 441 mg/kg (400 g/ton) chlortetracycline fed for 14 d (TIACTC) followed by 39 mg/kg (35 g/ton) tiamulin fed for 21 d (TIA) vs. 3) 28 mg/kg (25 g/ton) carbadox + 441 mg/kg (400 g/ton) oxytetracycline fed for 14 d (CAROTC) followed by 55 mg/kg (50 g/ton) carbadox fed for 21 d (CAR). Necropsy results from mortalities during the study confirmed the presence of pathogens including Pasteurella multocida and Escherichia coli, as well as Mycoplasma hyopneumoniae, Haemophilus parasuis, and Streptococcus suis. The study was carried out for a fixed time of 35 d from 6.7 ± 0.57 to 25.5 ± 2.23 kg BW. Pigs were housed in single-sex pens of 25 in a commercial wean-to-finish facility and there were 30 replicates of each treatment. All pigs were weighed as a group (i.e., pen) on days 0 (start), 14, and 35 (end) of study. Pigs had ad libitum access to feed and water throughout the study period; all feed additions to the feeder were recorded. There was no effect (P > 0.05) of antibiotic feeding program on the incidence of morbidity and mortality at any point during the study. During phase 1, TIACTC- and CAROTC-fed pigs were heavier (P < 0.05) at day 14 and had greater (P < 0.05) ADG (8.3% and 5.6% for TIACTC and CAROTC, respectively) and ADFI (4.3% and 6.5%, respectively) than controls. Pigs fed TIACTC in the first 14 d had greater (P < 0.05) G:F than the other treatments, which were similar for this measurement. In phase 2, feeding CAR resulted in greater (P < 0.05) ADG than controls, with pigs fed TIA being intermediate and different (P < 0.05) than the other treatments. Feeding antibiotics, regardless of treatment, resulted in greater (P < 0.05) ADFI than controls, but there were no differences in G:F. For the overall 35-d study period, feeding antibiotics resulted in greater (P < 0.05) ADG than controls (3.8% and 5.8%, respectively), but no difference (P > 0.05) between treatments for overall G:F. The results of this study confirm the advantage of feeding antibiotics on nursery pig growth.

Key words: antibiotics, growth, nursery, pigs

INTRODUCTION

Nursery pigs often face many stressors, which lead to suppressed immune function, increased...
rate of disease, and depressed growth performance (Cromwell et al., 2002; Dibner and Richards, 2005). In fact, Vervaeke et al. (1979) reported that up to 6% of the net energy in swine diets may be used to maintain health and the proper gut microflora balance. The majority of feed grade antibiotics is used to prevent, control, or treat disease (Dewey et al., 1999; Apley et al., 2012). One of the medication regimens commonly used includes feeding 39 mg/kg (35 g/ton) tiamulin with 441 mg/kg (400 g/ton) chlortetracycline (TIACTC) to nursery pigs. When used in combination, a synergistic effect exists between the two medications resulting in lower minimum inhibitory concentrations against bacterial pathogens than when used separately (Burch et al., 1986; Mills et al., 2008). This combination has been shown to reduce morbidity and mortality and increase growth performance compared to nonmedicated controls (Keegan et al., 2005; Steidinger et al., 2009; Sandberg et al., 2017). Another combination commonly fed to nursery pigs includes 28 mg/kg (25 g/ton) carbadox with 441 mg/kg (400 g/ton) oxytetracycline (CAROTC). Non-peer reviewed reports exist on the effectiveness of this enteric and respiratory treatment in nursery pigs, which generally demonstrate improvements in performance compared to nonmedicated controls (Steidinger et al., 2008). However, many of these previous studies focus on the outcome measures such as growth performance and not the underlying improved health or reduced immune stimulation. In addition, much of the previous research was done with relatively small numbers of animals in small research settings, and there is limited information for how these feeding programs influence health and growth performance traits in a commercial setting. Therefore, this study researched two nursery medication programs in nursery pigs housed in a commercial setting.

**MATERIALS AND METHODS**

Experimental procedures in this study were performed in accordance with the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (Federation of Animal Science Societies, 2010).

**Experimental Design and Treatments**

The study was carried out for a fixed-time of 35 d from 6.7 ± 0.57 kg to 25.5 ± 2.23 kg BW using a randomized complete block design (blocking factor was day of start on test). The study was conducted in two phases. Phase 1 was carried out for 14 d and evaluated three feeding programs: 1) control (no feed medication) vs. 2) TIACTC vs. 3) CAROTC. Phase 2 was carried out for 21 d and evaluated three feeding programs: 1) control (no feed medication) vs. 2) 39 mg/kg tiamulin (TIA) vs. 3) 55 mg/kg carbadox (CAR). Pigs fed TIACTC in phase 1 were fed TIA in phase 2. Similarly, pigs fed CAROTC in phase 1 were fed CAR in phase 2. A total of 2,250 crossbred pigs were housed in 90 single-sex pens. Replicates consisted of 3 pens (1 per dietary treatment) and there were 30 replicates per dietary treatment. Pen was the experimental unit for all growth performance measurements.

Antibiotics were fed in accordance to their Food and Drug Administration (FDA)–approved product labels including labeled dosage and durations.

**Animals and Allotment to Study**

Crossbred barrows and gilts that were the progeny of PIC 337 sires × C22 dams (PIC USA, Hendersonville, TN) were used in the study. A total of 90 single-sex pens, each housing 25 pigs, were stratified over two blocks that were used in the experiment. Allotment to the study was carried out within sex at weaning (approximately 21 d of age). At weaning, pigs were sorted by sex and placed into pens of 25 pigs with similar mean pen BW. Pens were randomly assigned to nursery treatments. Following allotment, pigs were allowed a 7-d acclimation period during which animals received nonmedicated diets prior to the start of feeding the experimental diets. At the end of the acclimation period, pen BW was collected and used as the initial BW of the study.

**Housing and Management**

Pigs were housed in a naturally ventilated, curtain-sided facility with fully slotted concrete floors. Pen dimensions provided a usable floor space of 16.25 m², which resulted in 0.65 m²/pig. Each pen was equipped with a four-space single-sided dry box feeder mounted on the pen division that provided 122 cm of total linear feeder space (4.88 cm/pig) and a single-cup water drinker.

**Diets and Feeding**

Prior to study, all animals received the same nonmedicated nursery starter diet. Experimental diets were fed beginning on approximately day 7 postweaning. This was designed to allow animals to acclimate...
to the facility, solid diets, and pen mates. A two-phase dietary program was used during the study: phase 1: fed from days 0 to 14 of study, and phase 2: fed from days 14 to 35 of study. Diets formulated to be typical of the production system’s standard nursery program were used. Diet formulations and calculated composition of the diets fed during the experimental period are presented in Table 1. Pigs had ad libitum access to feed and water throughout the study period.

**Growth Study Measurements**

All pigs were weighed as a group (i.e., pen) on day 0 (start of experimental feeding period), 14, and 35 (end). All feed additions to the feeders were recorded and the amount of feed remaining in the feeders was weighed at the time of pig weighing and used to calculate ADFI and G:F.

Incidence of morbidity and mortality was recorded for all pigs on the study. Morbidity was defined as any pig that was removed from study for any reason. Research technicians responsible for removing animals from study were not blinded to experimental treatments. Mortality was defined as any pig that died while on study. All pigs that died or were removed from study were weighed at that time and the weight was used to calculate total pig day for each pen to use in growth performance calculations.

**Statistical Analysis**

The PROC UNIVARIATE procedure of SAS (SAS Inst. Inc., Cary, NC) was used to verify normality and homogeneity of variance of the variables. All growth performance variables conformed to normality assumptions and were analyzed using PROC MIXED of SAS. The pen of pigs was the experimental unit for growth performance measurements (BW, ADG, ADFI, and G:F). The model included the fixed effect of dietary treatment and random effects of block and replicate nested within block. Sex was not included in the model but was accounted for as single-sex replicates were used in the study. Least-squares means were separated using the PDIFF option of SAS with means being considered different at a $P \leq 0.05$.

Morbidity and mortality data did not meet normality assumptions. As such, the PROC GLIMMIX procedure of SAS was used to analyze incidence levels of morbidity and mortality. The model included the fixed effect of treatment and the random effect of block. Least-squares means were separated using the PDIFF option of SAS with means being considered different at a $P \leq 0.05$.

**RESULTS AND DISCUSSION**

**Phase 1**

There was no difference ($P > 0.05$) between treatments for morbidity and mortality during phase 1 (Table 2). Pigs fed TIACTC or CAROTC were heavier ($P < 0.05$) than nonmedicated controls at the end of phase 1 (0.5 kg and 0.4 kg for TIACTC and CAROTC treatments, respectively). In addition, pigs fed TIACTC or CAROTC had greater ($P < 0.05$) ADG (8.3% and 5.6%, respectively)

### Table 1. Diet composition, as fed basis

| Item                          | Phase 1       | Phase 2       |
|-------------------------------|---------------|---------------|
| Days of study fed             | 0 to 14       | 14 to 35      |
| Ingredient (%)                |               |               |
| Corn                          | 56.27         | 64.63         |
| Soybean meal                  | 25.00         | 30.75         |
| Fat, choice white grease      | 2.00          | 1.50          |
| Dical                         | 0.75          | 1.20          |
| Limestone                     | 0.45          | 0.60          |
| Salt                          | 0.30          | 0.50          |
| l-Lysine                      | 0.35          | 0.36          |
| Methionine hydroxy analogue   | 0.22          | 0.16          |
| l-threonine                   | 0.16          | 0.10          |
| Plasma                        | 2.00          | —             |
| Lactose                       | 7.50          | —             |
| Fish meal                     | 4.50          | —             |
| Zinc oxide                    | 0.30          | —             |
| Copper sulfate                | 0.05          | 0.05          |
| Vitamin premix                | 0.05          | 0.05          |
| Trace mineral premix          | 0.10          | 0.10          |
| Total                         | 100           | 100           |
| Calculated composition        |               |               |
| ME (Mcal/kg)                  | 3.47          | 3.40          |
| CP (%)                        | 21.83         | 20.46         |
| Total Lys (%)                 | 1.54          | 1.38          |
| SID Lys (%)                   | 1.40          | 1.25          |
| Available P (%)               | 0.51          | 0.41          |
| Ca (%)                        | 0.73          | 0.62          |
| SID Met + Cys:Lys             | 58.61         | 58.06         |
| SID Thr:Lys                   | 62.46         | 60.13         |
| SID Trp:Lys                   | 16.06         | 17.04         |
| SID Ile:Lys                   | 55.86         | 60.05         |
| SID Val:Lys                   | 65.25         | 66.87         |

SID = Standardized ileal digestible.

*Respective antibiotics were added to diets at the expense of corn.

*Trade name: DairyLac 80 (International Ingredient Corporation, St. Louis, MO).

*Provided per kg of final diet: 6,600 IU vitamin A, 704 IU vitamin D$_3$, 26 IU vitamin E, 4.9 mg riboflavin, 2.6 mg menadione, 0.02 mg vitamin B$_12$, 16.5 mg d-pantothenic acid, and 29.7 mg niacin.

*Provided per kg of final diet: 66 mg iron, 66 mg zinc, 19.8 mg manganese, 66 mg copper, 14 mg iodine, and 0.12 mg selenium.
and ADFI (4.3% and 6.5%, respectively) than controls. There was no difference \((P > 0.05)\) in ADG or ADFI between pigs fed TIACTC or CAROTC. G:F was improved \((P < 0.05)\) for pigs fed TIACTC by 4.1\% vs. controls and 4.8\% vs. pigs fed CAROTC (Table 2).

**Phase 2**

There was no difference \((P > 0.05)\) between treatments for the incidence of morbidity and mortality during phase 2 (Table 2). Pigs fed TIA or CAR were heavier \((P < 0.05)\) than nonmedicated controls at the end of phase 2 (0.7 kg and 1.0 kg for TIA and CAR treatments, respectively). Pigs fed CAR had 3.1\% greater \((P < 0.05)\) ADG than pigs fed TIA, which had 3.2\% greater \((P < 0.05)\) ADG than controls. For phase 2, ADFI was lower \((P < 0.05)\) for nonmedicated controls than pigs fed TIA or CAR, which were similar for this parameter. During phase 2, there was no difference \((P > 0.05)\) between the treatments for G:F (Table 2).

**Overall**

For the overall 35-d study period, there was no difference \((P > 0.05)\) between treatments for the overall incidence of morbidity and mortality. However, nonmedicated controls had lower \((P < 0.05)\) overall ADG than pigs fed diets containing antibiotics. Pigs fed CAROTC followed by CAR had greater \((P < 0.05)\) overall ADFI than nonmedicated controls, with pigs fed TIACTC followed by TIA being intermediate and different \((P < 0.05)\) than the other treatments. There was no difference \((P > 0.05)\) observed between treatments for overall G:F in this study (Table 2).

### Table 2. Effects of antibiotic feeding program on the growth performance of nursery pigs

| Item                      | Control | TIACTC\(^1\) | CAROTC\(^1\) | SEM  | \(P\)-value |
|---------------------------|---------|--------------|--------------|------|-------------|
| No. of pens               | 30      | 30           | 30           | —    | —           |
| Phase 1 (days 0 to 14)    |         |              |              |      |             |
| BW, kg                    |         |              |              |      |             |
| Day 0 (start)             | 6.7     | 6.6          | 6.7          | 0.45 | 1.00        |
| Day 14                    | 11.7\(^b\) | 12.2\(^a\) | 12.1\(^a\) | 1.10 | 0.01        |
| ADG, kg                   | 0.36\(^a\) | 0.39\(^a\)  | 0.38\(^a\)  | 0.046| <0.001      |
| ADFI, kg                  | 0.46\(^a\) | 0.48\(^a\)  | 0.49\(^a\)  | 0.053| <0.001      |
| G:F, kg:kg                | 0.780\(^a\) | 0.812\(^a\) | 0.775\(^a\) | 0.0120| <0.001    |
| Morbidity and mortality   |         |              |              |      |             |
| No. of pigs               | 7       | 12           | 10           | —    | —           |
| Percentage of pigs        | 0.93    | 1.60         | 1.33         | 0.361| 0.43        |
| Phase 2 (days 14 to 35)   |         |              |              |      |             |
| BW, kg                    |         |              |              |      |             |
| Day 14                    | 11.7\(^b\) | 12.2\(^a\) | 12.1\(^a\) | 1.10 | 0.01        |
| Day 35 (end)              | 25.0\(^b\) | 25.7\(^a\) | 26.0\(^a\) | 1.91 | <0.001      |
| ADG, kg                   | 0.62\(^a\) | 0.64\(^a\)  | 0.66\(^a\)  | 0.039| <0.001      |
| ADFI, kg                  | 0.94\(^a\) | 0.98\(^a\)  | 1.00\(^a\)  | 0.078| <0.001      |
| G:F, kg:kg                | 0.663   | 0.656        | 0.663        | 0.0116| 0.11     |
| Morbidity and mortality   |         |              |              |      |             |
| No. of pigs               | 8       | 7            | 5            | —    | —           |
| Percentage of pigs        | 1.08    | 0.96         | 0.69         | 0.372| 0.61        |
| Overall (days 0 to 35)    |         |              |              |      |             |
| ADG, kg                   | 0.52\(^a\) | 0.54\(^a\)  | 0.55\(^a\)  | 0.042| <0.001      |
| ADFI, kg                  | 0.75\(^a\) | 0.78\(^a\)  | 0.79\(^a\)  | 0.068| <0.001      |
| G:F, kg:kg                | 0.692   | 0.695        | 0.690        | 0.0055| 0.39     |
| Morbidity and mortality   |         |              |              |      |             |
| No. of pigs               | 15      | 19           | 15           | —    | —           |
| Percentage of pigs        | 2.00    | 2.53         | 2.00         | 0.575| 0.73        |

\(^{a,b}\)Means within a row with different superscripts are significantly different \((P < 0.05)\).

\(^1\)39 mg/kg (35 g/ton) tiamulin + 441 mg/kg (400 g/ton) chlortetracycline fed from days 0 to 14 followed by 39 mg/kg (35 g/ton) tiamulin fed from days 14 to 35.

\(^2\)28 mg/kg (25 g/ton) carbadox + 441 mg/kg (400 g/ton) oxytetracycline fed from days 0 to 14 followed by 55 mg/kg (50 g/ton) carbadox fed from days 14 to 35.
In the current study, growth rate during phase 1 was improved by 8.3% and feed conversion was improved by 4.8% from feeding TIACTC compared to nonmedicated controls. Feeding TIACTC to nursery pigs has been shown to improve the growth rate and feed conversion of nursery pigs when compared to nonmedicated controls in a number of studies (Steidinger et al., 2008; Potter et al., 2009; Steidinger et al., 2009; Sandberg et al., 2017). However, these studies fed TIACTC for either shorter (10 d) or longer (21 d) than the 14-d feeding period used in the current study. Generally, these studies showed greater improvements than those observed in the current study. Gottlob et al. (2004) fed TIACTC for 14 d and reported a 23.1% improvement in overall growth rate but no difference in feed intake or conversion. All of these studies were initiated immediately postweaning, when feed intake in young nursery pigs can be highly variable (Pajor et al., 1991; Bruininx et al., 2001). In the current study, pigs were acclimated to the facility for 7 d prior to the start of the study, and perhaps this can explain, in part, the differences in response rates from feeding TIACTC. Nonetheless, the results of the current study substantiate previous research confirming the advantages in growth performance from feeding TIACTC compared to nonmedicated controls in the nursery period.

Non–peer reviewed reports demonstrate growth performance benefit obtained from feeding CAROTC. Steidinger et al. (2008) reported improved growth rate and feed conversion from feeding CAROTC compared to nonmedicated controls. Interestingly, these authors also showed TIACTC had greater overall ADG compared with pigs fed CAROTC, with no difference in feed conversion (Steidinger et al., 2008), results which are in contrast to the current study.

Peer-reviewed research is lacking in the comparison of TIA vs. CAR in nursery pigs. Typically, when TIA is included in nursery swine diets, it is included as TIACTC, and therefore, there is limited information on the sole effects of TIA in nursery diets. As such, the current study documents the direct performance differences of TIA and CAR in nursery pigs. In the current study, pigs fed CAR had 3.1% greater growth rate than pigs fed TIA, but feed intake and feed conversion did not differ between the antibiotic treatments. Carbbox has both a therapeutic and growth performance claim when fed at 55 mg/kg in nursery diets (FDA, 1998). However, TIA only has a therapeutic claim when fed at 38 mg/kg (FDA, 2001), thus, it was somewhat expected that pigs fed CAR would have superior growth performance to those fed TIA. Zimmerman (1986) performed a literature review and reported a 17.1% improvement in growth rate and 7.0% improvement in feed conversion compared to controls from feeding CAR to nursery pigs. Gottlob et al. (2004) reported a 9.7% improvement in growth rate and 6.8% improvement in feed conversion from feeding CAR at 55 mg/kg in the nursery period. However, Wilt and Carlson (2009) reported no improvement in growth performance from feeding 55 mg/kg CAR compared to controls. More recently, Shawk et al. (2018) reported increased growth rate and feed intake, but no difference in feed conversion, for pigs fed 55 mg/kg CAR compared to controls. In the current study, growth rate was improved by 6.5% for pigs fed CAR and 3.2% for pigs fed TIA compared to controls. These results are slightly lower than the majority of previous reports but generally within expectations.

For the overall study period, there were small differences between the antibiotic feeding programs. Regardless of antibiotic feeding program, pigs fed antibiotics during the nursery period had improved growth rate and feed intake compared to nonmedicated controls. The majority of previous research well documented that including medications in nursery swine diets improves growth performance (Stahly et al., 1980; Cromwell et al., 2002; Gottlob et al., 2004). In a recent study, Grohmann et al. (2017) reported a 1.8% improvement in nursery ADG and 2.7% greater ADFI for nursery pigs fed or administered antibiotics vs. nonmedicated controls, but reported no improvement in feed conversion, results similar to this study. Many of these studies, as well as this study, housed treated and control animals in adjacent pens. In theory, this could have altered pathogen exposure for each treatment group. For controls, the overall environmental pathogen exposure would have been reduced by animals consuming antibiotics, and thus, this may have resulted in greater than expected performance by controls. In addition, animals fed antibiotics may have had greater overall pathogen exposure by being housed adjacent to controls, and this may have lessened the performance benefit of feeding antibiotics in the current study. Generally speaking, however, the increases in growth performance observed in the current study for animals fed antibiotics are within expected levels based on previous research.

Previously reported improvements in morbidity and mortality are inconsistent and may depend on levels observed in the facility and the various health challenges faced by groups of weaning
pigs. Sandberg et al. (2017) reported significantly less mortality from feeding TIACTC and CAR in the nursery period, whereas other studies have not (Stahly et al., 1980; Grohmann et al., 2017). Mortality and morbidity are generally late indicators of illness, and growth parameters are early indicators of subclinical or preclinical illness.

The pigs used in the current study were of relatively high health as demonstrated by the low morbidity and mortality in all treatment groups. However, the situation of using morbidity and mortality to initiate treatment is a decision made late in the clinical disease and is often after performance has already significantly dropped. In contrast, growth and feed intake are better estimates of subclinical or preclinical disease, improving the welfare and care of the animals. The results of the current study confirm the advantages of feeding antibiotics in nursery swine diets and provide a baseline for the expected performance decline if a producer decides to raise antibiotic-free pigs or wait until clinical disease is observed.

Conflict of interest statement. None declared.

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