Effects of 3-methylindole production and immunity against bovine respiratory syncytial virus on development of respiratory tract disease and rate of gain of feedlot cattle

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Objective—To determine whether immunity against bovine respiratory syncytial virus (BRSV) mitigates the effects of 3-methylindole (3MI) on occurrence of bovine respiratory tract disease (BRD) and rate of gain in feedlot cattle.

Animals—254 mixed-breed beef cattle.

Procedure—Cattle were randomly assigned to 1 of 3 groups at the time of arrival at the feedlot. One group was vaccinated with an inactivated BRSV vaccine, another was vaccinated with a modified-live BRSV vaccine, and the third was maintained as unvaccinated control cattle. On days 0 and 28, serum BRSV antibody concentrations were measured, using serum neutralizing and ELISA techniques. Serum 3MI concentrations were measured at feedlot arrival and 3 days later. Cattle were monitored for development of BRD. At slaughter, lungs were evaluated grossly for chronic lesions.

Results—Higher serum 3MI concentrations early in the feeding period were associated with lower mean daily gain. Control cattle were more likely to be treated for BRD after day 3, compared with cattle vaccinated with the modified-live BRSV vaccine. Humoral immunity against BRSV did not appear to modify the effect of 3MI on development of BRD or mean daily gain.

Conclusions and Clinical Relevance—Results suggest that abrogating the effects of 3MI and BRSV infection may improve the health and growth performance of feedlot cattle. However, in this study, immunity against BRSV did not appear to protect against the potential synergism between 3MI and BRSV infection, possibly because of the slow rates of gain of cattle included in the study or timing of sample collection. (*Am J Vet Res* 2000;61:1309–1314)

In feedlot cattle, **bovine respiratory tract disease (BRD)** is a complex, multifactorial disease, and many exposures contribute to the overall occurrence of BRD. Recently, **3-methylindole (3MI)** and **bovine respiratory syncytial virus (BRSV)** were found to act synergistically, and cattle experimentally exposed to a combination of 3MI and BRSV had a greater mortality rate, greater lung weight, greater lung displacement volume, and more severe lung lesions, compared with cattle challenge exposed with 3MI or BRSV alone.[1]

All cattle produce 3MI through metabolism of tryptophan by *Lactobacillus* spp in the rumen.[2,3] However, cattle that have recently entered a feedlot may experience a sudden increase in 3MI production. Feed intake of cattle is generally limited while they move through public cattle auctions and during transportation to feedlots. After entering the feedlot, cattle are fed abundant quantities of high-quality feed, and an abrupt change in diet combined with intake of large amounts of high-quality protein is known to increase serum and rumen 3MI concentrations in adult cattle.[4,5] Serologic data also suggest that cattle are commonly exposed to BRSV while in the feedlot,[6-10] and the concurrent increase in 3MI production and BRSV exposure may account for a proportion of the cases of BRD among feedlot cattle.[11]

The purposes of the study reported here were to evaluate the effect of 3MI production on respiratory disease and rates of gain of feedlot cattle and to determine whether immunity against BRSV would mitigate the effects of 3MI production.

Materials and Methods

Study population and design—Two hundred fifty-four mixed-breed beef cattle purchased from a commercial auction market in southern Ohio were used in the study. Vaccination and disease histories of the cattle were not known. Cattle were purchased in 3 groups during a 6-week period in the fall of 1996. They were transported approximately 60 miles from the auction market to a feedlot operated by the Ohio Department of Rehabilitation and Correction.[a] Upon arrival, they were given access to grass hay, concentrate mix (0.9 kg/calf [2.0 lb/calf]), and water. The following morning (day 0), they underwent a series of procedures collectively known as processing. At the time of processing, all cattle were individually identified with nonse-

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quentially numbered ear tags, weighed, and assigned to 1 of 3 groups. Group-1 cattle received an inactivated BRSV[b] vaccine on day 0 and day 14, group-2 cattle received a modified-live BRSV[c] vaccine on day 0 and day 14, and group-3 cattle served as unvaccinated controls. A systematic randomization procedure was used to assign cattle to groups. Briefly, group assignment of the first animal processed was randomly selected, and the order that cattle would be assigned to groups was randomized. Cattle were then assigned to each group in this randomized order (every third animal was assigned to the same group) until all cattle were assigned to treatment groups in approximately equal numbers. Cattle assigned to the 3 groups were commingled in approximately equal numbers in each pen at the feedlot. Treatment group assignments were recorded by an individual not involved in the remainder of the study, and personnel involved in the study were not aware of which cattle were assigned to which group. The assignment code was broken only after all cattle involved in the study were slaughtered.

At the time of processing, all cattle were vaccinated with a modified-live bovine herpesvirus type 1, bovine viral diarrhea virus, and parainfluenza virus type 3 vaccine and with a *Mannheimia haemolytica, Pasteurella multocida, Haemophilus somnus*, and multivalent *Clostridium* spp bacterin. Cattle were also treated with ivermectin (0.2 mg/kg of body weight, SC) and dehorned and castrated as necessary.

Clinical assessment—Rectal temperatures of the cattle were recorded during processing (day 0) and on days 3, 14, and 28. Feedlot personnel observed the cattle once daily, and any cattle that appeared sick were isolated for closer examination. Cattle were considered to have BRD if they had a rectal temperature > 40 C and did not have clinical abnormalities referable to disease of any other organ system. Cattle that developed BRD were treated with tilmicosin phosphate[d] (9.9 mg/kg, SC, as needed) or florfenicol[e] (19.8 mg/kg, IM, as needed). Throughout the feeding period, feedlot personnel responsible for identifying and treating sick cattle recorded the presumptive diagnosis, antimicrobial drug used, dose, route of administration, and date of treatment. Cattle were returned to the pen of origin after examination and treatment. After 40 to 60 days at this feedlot, cattle were transported to 1 of 3 additional feedlots operated by the Ohio Department of Rehabilitation and Correction[a] and fed for the remainder of the finishing period.

Postmortem assessment—Estimated finished weight of the cattle was calculated by multiplying hot carcass weight by 1.667 (ie, expected dressing percentage). Carcass trim was not observed; therefore, hot carcass weight was not adjusted for carcass trim. Lungs of all cattle were evaluated for gross lesions within 6 hours after slaughter by a single investigator (HRB). Lung weight was recorded for each animal after excess mediastinal tissue, pericardial tissue, and trachea were trimmed away. Each lung lobe was evaluated for chronic lesions (eg, consolidation, fibrosis).

Laboratory analyses—Blood samples were collected from all cattle on days 0 and 3, and serum was obtained for determination of serum 3MI concentrations. Blood samples were also collected on days 0 and 28 for determination of BRSV antibody concentrations using **serum neutralizing (SN)** and ELISA techniques. Blood samples were placed on ice in a dark cooler for transport to the laboratory. Aliquots of serum were frozen within 8 hours after collection and stored at –20 C until analyzed.

Serum 3MI concentrations were measured by use of a colorimetric assay, adapted from a described technique.[12] Briefly, samples were extracted with absolute ethanol and then centrifuged.[1,12] The supernatant was mixed with a solution containing 4-dimethylaminobenzaldehyde, which reacted with 3MI to form a purple product. Optical density was measured spectrophotometrically, and the concentration of 3MI was then determined by comparing results with a standard curve.[1,12]

Bovine respiratory syncytial virus SN antibody titers were measured, using a standard protocol,[13] at the Ohio Department of Agriculture Animal Disease Diagnostic Laboratory.[f] Briefly, test sera were diluted 1:2 with Eagle **minimum essential medium (MEM)** with gentamicin and inactivated at 56 C for 30 minutes in a water bath. Aliquots (50 µl) were placed in wells on 96-well microtitration plates in duplicate, and 2-fold serial dilutions were made, using 25 µl of MEM. Bovine respiratory syncytial virus grown on bovine turbinate cells was added to all wells (25 µl containing 100 to 500 median tissue culture infective doses of BRSV). Contents of the wells were mixed, and plates were then incubated at 37 C in a moist 5% CO_2 environment. The wells were evaluated for cytopathic effect after 7 days of incubation. The highest dilution of serum that inhibited cytopathic effects in both wells was considered the titration endpoint for the serum sample. Seroconversion to BRSV in this assay was defined as a 4-fold increase in the SN antibody titer. The base 2 logarithms of BRSV SN antibody titers were used for data analysis.

Serum BRSV antibody concentrations were measured, using a whole-cell ELISA as described.[14] This assay is believed to measure total BRSV-specific IgG (neutralizing and nonneutralizing antibody) concentration.[14] Seroconversion to BRSV with this ELISA was defined as a 20-unit increase in ELISA value.[14] The ratio of BRSV SN titer to BRSV ELISA antibody concentration was calculated as a relative measure of neutralizing and nonneutralizing antibody production.[14]

Data analyses—Descriptive statistics were calculated, and data were examined graphically or in tabular form. Outcomes of interest for inferential analysis were mean daily gain (calculated as [estimated finish weight–entry weight] / total number of days in the feedlot), development of BRD during the first 3 days at the feedlot (ie, disease that most likely was initiated prior to transport to the feedlot or that likely would not have been influenced by vaccination against BRSV at the time of arrival), development of BRD after day 3 (ie, disease that most likely was initiated after entry to the feedlot and for which vaccination may have influenced disease occurrence), and detection of chronic pulmonary lesions at the time of slaughter (ie, respiratory disease that was not detected clinically or did not completely resolve with treatment[15]).

The independent variables of interest were maximum observed serum 3MI concentration (ie, the higher of the day 0 and day 3 serum 3MI concentrations) after feedlot entry, serum BRSV SN antibody titer and BRSV ELISA antibody concentration at the time of arrival at the feedlot, treatment group, and the interactions between serum 3MI concentration and measures of immunity to BRSV (initial antibody titers and concentrations and treatment group). Multivariable logistic regression[g] was used to assess the effect of the independent variables on the 3 dichotomous (yes vs no) disease outcomes. The effect of vaccination on incidence of BRD during the first 3 days at the feedlot was not evaluated, because it was unlikely that vaccination affected the occurrence of BRD during this period. Multivariable ANOVA was used to assess the effect of independent variables on mean daily gain.

For each outcome, an initial model was specified that included the independent variables of primary interest—serum BRSV SN antibody titer at the time of arrival at the

feedlot or treatment group and maximum observed serum 3MI concentration. Serum BRSV ELISA antibody concentrations at the time of arrival at the feedlot were evaluated in the same manner but in separate models.

Additional variables assessed for potential confounding included purchase group (lot), feedlot where cattle were finished, sex, body weight on day 0, treatment with antimicrobial drugs between day 0 and 3 (for the analysis of development of BRD after day 3), dehorning, and castration. The design variable representing purchase group was forced into all models, because of the potential confounding effect on outcome variables. Other potential confounding variables were evaluated by use of a manual forward selection process with a critical α for retention of 0.05. Once all potential confounding variables had been evaluated, interactions between maximum observed serum 3MI concentration and measures of immunity against BRSV (antibody titer or antibody concentration at the time of arrival at the feedlot or treatment group assignment) were assessed to determine whether immunity against BRSV, as measured by these variables, would mitigate the effects of increased 3MI production on the occurrence of BRD and rate of gain.

Least-square mean daily gain was compared among treatment groups by use of the Tukey-Kramer method of correction. Goodness-of-fit of final linear regression models was evaluated visually, by graphing the predicted values versus the residual for the dependent variable.[16] Effects on development of BRD were evaluated by estimating **odds ratios (OR)** and exact 95% **confidence intervals (CI)** and by estimating the likelihood ratio χ^2. Final logistic regression models were evaluated for goodness-of-fit by use of the Hosmer-Lemeshow statistic.[17] McNemar's test for correlated proportions was used to evaluate differences between seroconversion rates based on BRSV ELISA antibody concentrations versus BRSV SN antibody titers.

Results

Descriptive results—Mean ± SD weight of the cattle at the time of arrival at the feedlot was 269 ± 42 kg. One hundred six (42%) were heifers, and 148 (58%) were steers. Twenty-four (9%) cattle were dehorned, and 4 (2%) were castrated during processing. Cattle were fed for an average of 269 ± 105 days (mean ± SD) prior to slaughter. There were no differences in mean weight at the time of arrival, sex distribution, dehorning or castration rates, or mean number of days fed prior to slaughter among treatment groups.

Eighty-eight (35%) cattle were treated for BRD during the first 3 days after arrival at the feedlot, and 27 (10%) were treated after day 3. Most cattle (25/97) were only treated once for BRD. All cattle that developed BRD did so within 2 weeks after arrival at the feedlot. Overall, 6 cattle (2.4%) died; mortality rate was not significantly different among treatment groups. All cattle that died of BRD came from a single purchase group. Crude mean ± SD daily gain was 0.95 ± 0.18 kg. Lung consolidation was observed in lungs from 23 cattle (9.1%), and pleural fibrosis was observed in lungs from 65 cattle (25.6%) at slaughter.

Laboratory findings—Natural exposure to BRSV was common among these cattle. On the basis of BRSV ELISA concentrations, 53 of 83 (64%) control cattle surviving to day 28, all 83 surviving cattle vaccinated with the inactivated BRSV vaccine, and 75 of 83 (90%) surviving cattle vaccinated with the modified-live BRSV vaccine seroconverted to BRSV. On the basis of BRSV SN antibody titer, 53 of 83 (64%) surviving control cattle, 76 of 83 (92%) surviving cattle vaccinated with the inactivated BRSV vaccine, and 80 of 83 (96%) surviving cattle vaccinated with the modified-live BRSV vaccine seroconverted to BRSV. Percentages of cattle that were considered to have seroconverted on the basis of antibody concentrations versus antibody titers were not statistically different; however, percentage of control cattle that seroconverted, determined on the basis of BRSV SN antibody titers, was lower ($P < 0.01$) than percentages of cattle in the other 2 groups that did. The crude day-28 mean serum BRSV ELISA antibody concentration for cattle vaccinated with the inactivated BRSV vaccine was significantly ($P < 0.001$) higher than mean concentration for the other groups (**Table 1**). The crude day-28 mean serum BRSV SN antibody titer for the control cattle was lower ($P < 0.01$) than mean titers for the other groups. The crude day-28 mean ratio of SN antibody titer-to-ELISA antibody concentration was highest ($P < 0.01$) for cattle vaccinated with the modified-live virus vaccine, followed by the control cattle and the cattle vaccinated with the inactivated virus vaccine.

Overall mean ± SD serum 3MI concentrations on days 0 and 3 were 2.21 ± 1.21 µg/ml (median, 2.04 µg/ml; range, 0.05 to 7.05 µg/ml) and 1.85 ± 1.16 µg/ml (median, 1.54 µg/ml; range, 0.00 to 9.04 µg/ml), respectively. Serum 3MI concentrations on day 0 were higher ($P < 0.001$) than concentrations on day 3.

Table 1—Measures of immunity to bovine respiratory syncytial virus (BRSV) among feedlot cattle vaccinated with an inactivated BRSV vaccine (n = 85) on days 0 and 14 or vaccinated with a modified-live BRSV vaccine (85) on days 0 and 14, and among control cattle (84)

Variable	Control	Inactivated-virus vaccine	Modified-live virus vaccine
ELISA antibody concentration			
Day 0	22.5 ± 3.0[a]	28.9 ± 3.31[a]	23.8 ± 3.0[a]
Day 28	58.6 ± 3.4[a]	117.5 ± 5.04[b]	70.0 ± 3.0[a]
Serum neutralizing antibody titer*			
Day 0	1.8 ± 0.4[a]	2.0 ± 0.4[a]	2.2 ± 0.4[a]
Day 28	17.6 ± 5.3[a]	48.0 ± 9.6[b]	51.2 ± 10.2[b]
Ratio†			
Day 0	0.0204 ± 0.0040[a]	0.0182 ± 0.0033[a]	0.0234 ± 0.0040[a]
Day 28	0.0638 ± 0.0042[a]	0.0485 ± 0.0018[b]	0.0862 ± 0.0033[c]

Data are given as mean ± SEM.
*Geometric mean titer. †Ratio of serum neutralizing antibody titer-to-ELISA antibody concentration.
[a–c]In each row, values with different superscript letters are significantly ($P < 0.05$) different.

Serum 3MI concentrations were not statistically different among treatment groups on day 0 or day 3.

Clinical findings—The final models evaluating associations between development of BRD during the first 3 days and the independent variables of interest (maximum serum 3MI concentration and serum antibody concentrations at arrival) also included variables for weight at the time of arrival at the feedlot and purchase group. Maximum serum 3MI concentration was not associated with development of BRD during the first 3 days after arrival at the feedlot (OR, 1.05; 95% CI, 0.84 to 1.33). Each 2-fold decrease in serum BRSV SN antibody titer at the time of arrival was associated with a slight increase, although not a statistically detectable difference, in the odds of developing BRD during the first 3 days in the feedlot (OR, 1.16; 95% CI, 0.98 to 1.43). A statistical interaction was not detected between serum 3MI concentration and BRSV SN antibody titer, suggesting that this measure of immunity did not measurably modify any effect 3MI concentration had on development of BRD.

The final models evaluating associations between development of BRD after day 3 and the independent variables of interest (maximum serum 3MI concentration and serum antibody concentrations at arrival or treatment group) included variables for sex and purchase group. A 1-µg/ml increase in maximum serum 3MI concentration was associated with a slight increase, although not a statistically detectable difference, in the likelihood of developing BRD after day 3 (OR, 1.3; 95% CI, 0.93 to 1.93). A 10-unit decrease in serum BRSV ELISA antibody concentration at arrival was associated with increased odds of developing BRD after day 3 (OR, 1.32; 95% CI, 1.05 to 1.82). Cattle in the control group (OR, 3.2; 95% CI, 1.00 to 12.08) were more likely to be treated for BRD after day 3, compared with cattle that received the modified-live BRSV vaccine. A statistical interaction was not detected between 3MI concentration and BRSV SN antibody titer, suggesting that this measure of immunity did not measurably modify any effect 3MI concentration had on development of BRD.

Mean daily gain—The final model evaluating associations between mean daily gain and the variables of interest (maximum serum 3MI concentration and serum antibody concentrations at arrival or treatment group) included variables for sex and feedlot where cattle were finished. A 1-µg/ml increase in maximum serum 3MI concentration was associated with a decrease ($P = 0.02$) in mean daily gain of 0.02 ± 0.01 kg (mean ± SEM). Serum SN antibody titer and ELISA antibody concentration at the time of arrival at the feedlot were not associated with mean daily gain. Cattle vaccinated with the inactivated BRSV vaccine gained more per day ($P = 0.08$; mean ± SEM mean daily gain, 0.06 ± 0.03 kg) than did control cattle. Differences in mean daily gain among other treatment groups were not detected. A statistical interaction between immunity against BRSV (ie, day-0 antibody concentrations or treatment group) and 3MI concentration was not detected, suggesting that immunity did not measurably modify any effect 3MI concentration had on mean daily gain.

Postmortem findings—Detection of lung consolidation or fibrosis was not associated with maximum serum 3MI concentration, BRSV antibody titer or antibody concentration at arrival, or treatment group.

Discussion

In the present study, statistical interactions between maximum serum 3MI concentration and measures of immunity against BRSV, either vaccination with a modified-live or inactivated BRSV vaccine or SN antibody titer or ELISA antibody concentration at the time of arrival at the feedlot, were not detected. This suggests that there was no detectable synergy between BRSV and 3MI in development of BRD in these cattle or that immunity to BRSV, as measured in this study, did not protect against this synergy. However, higher serum 3MI concentrations at arrival were associated with lower mean daily gain and a small increase in the odds that cattle would develop BRD after day 3. This suggests that 3MI production, as measured in this study, had a negative effect on these cattle, and that mitigation of the effects of 3MI production in cattle at the time of arrival at the feedlot may improve weight gain and slightly diminish the risk of BRD.

Bovine respiratory disease is an economically important disease to cattle producers. The estimated economic loss attributable to cattle that died of BRD in 1996 was $485 million.[18] Research efforts have identified many factors causally related to development of BRD in feedlot cattle, including exposure to several infectious agents. However, while recent research has explored potential interaction among infectious agents that cause BRD,[19-22] little research has explored the interaction between infectious and noninfectious causes of BRD in feedlot cattle.

3-Methylindole is a natural product of L-tryptophan metabolism and causes acute pulmonary edema and emphysema in cattle.[4,5,23-25] Abruptly moving cattle from poor quality forages to better quality diets has been shown to result in higher rumen concentrations of 3MI.[4,5] Cattle are commonly moved from poor quality autumn pastures and through public cattle auction markets before transportation to a feedlot. During this transition period, they have decreased access to feed and decreased feed intake, whereas they typically have access to abundant quantities of high quality feed after entering the feedlot. This abrupt dietary change may lead to increased rumen and serum concentrations of 3MI.

Cattle from many sources are commingled at public cattle auction markets and in feedlots, exposing naive cattle to many infectious pathogens. Seroepidemiologic studies have found that exposure to BRSV is common,[6-10] and that cattle entering feedlots with low serum BRSV antibody titers were at greater risk for development of respiratory tract disease.[26] It is possible that a proportion of the production losses eventually attributed to BRSV infection may be affected by increased production of 3MI at the time of infection. 3-Methylindole has been shown to typically initiate clinical signs of respiratory tract disease within 2 weeks after an abrupt dietary change.[27,28] In cattle, serum concentrations of 3MI decrease to baseline values within 48 hours after oral administration of L-tryptophan[25] or

3MI,[24] suggesting that it would be possible for 3MI concentrations to increase and return to baseline prior to the time that clinical signs of respiratory tract disease are observed in feedlot cattle. Although we found an association between increased serum 3MI concentration and decreased mean daily gain, the limited number of times we measured serum 3MI concentration (days 0 and 3) may have inhibited our ability to detect a stronger association between serum 3MI concentration and mean daily gain or the occurrence of BRD.

Results of the present study suggest that mean daily gain was negatively affected by 3MI production in these cattle. In a previous study,[25] severity of pulmonary lesions in cattle was related to maximal plasma 3MI concentration and to duration of elevated plasma 3MI concentrations. Serum 3MI concentration in cattle in the present study ranged from 0.00 to 9.04 µg/ml during the 2 days that it was measured. Mature cattle given L-tryptophan, or in which the diet is abruptly changed, that develop respiratory tract disease attributable to 3MI had rumen 3MI concentrations ranging from 3.0 to 9.5 µg/ml.[4,5,25]

Results of a previous study[1] suggest that 3MI and BRSV may act synergistically to produce more severe respiratory disease. Although serum BRSV antibody concentrations did not appear to mitigate any potential synergy between BRSV and 3MI in the present study, mitigating the effects of 3MI alone may be important for cattle entering feedlots because of 3MI's effects as a pulmonary pneumotoxin and potential interactions with BRSV.

The association in the present study between serum BRSV ELISA antibody concentration at the time of arrival at the feedlot and development of BRD after day 3 corroborated findings of a previous study[26] and emphasizes the importance of BRSV immunity among cattle entering feedlots.

Inactivated and modified-live BRSV vaccines were used in this study, because there have been suggestions that either the inactivated or modified-live virus vaccine could potentiate respiratory tract disease.[14,29,30] More severe respiratory tract disease has been reported when modified-live BRSV vaccines were administered to cattle concurrently infected with BRSV.[29] Others have suggested that inactivated BRSV vaccines may not be as efficacious, compared with modified-live BRSV vaccines, because inactivated vaccines induce disproportionately higher concentrations of nonneutralizing antibody than modified-live virus vaccines.[14,30] Results of the present study also indicated that the inactivated virus vaccine induced production of more nonneutralizing antibody but similar amounts of neutralizing antibody. Work in humans and cotton rats with the human respiratory syncytial virus suggest that the production of nonneutralizing antibody by formalin-inactivated respiratory syncytial virus vaccines may be caused by critical changes in the antigenic epitopes of the F or G glycoproteins, and that higher concentrations of non-neutralizing antibody may potentiate disease when vaccinates are subsequently naturally exposed to the virus.[31,32] In the present study, the proportion of control cattle seroconverting suggested that natural exposure to BRSV was common during the first 30 days in the feedlot. Data obtained from this study, however, do not support the suggestion of immunopotentiation by the inactivated or modified-live BRSV virus vaccines during the first 30 days in the feedlot. The proportions of cattle that developed BRD or died were similar among treatment groups. This may be attributable to the timing of BRSV exposure versus timing of the development of protective immunity stimulated by vaccination against BRSV. Wikse[33] has suggested that preventive measures against BRD initiated at the time of feedlot arrival may be applied too late in the beef production cycle to mitigate proliferation and shedding of some infectious respiratory pathogens. All cattle in the present study that developed BRD did so within the first 2 weeks after arrival at the feedlot. However, amnestic responses from cattle previously exposed to BRSV may account for the slight protective effect of vaccination with the modified-live virus vaccine detected in the present study.

In the present study, weight of individual cattle at slaughter was estimated by multiplying the hot carcass weight by a factor of 1.667. Comparisons of mean daily gain among treatment groups were based on the assumption that this factor would be uniform across the study population and that any inaccuracy in the exact dressing percentage would not affect the comparisons of mean daily gain.

The inability to find an association between detection of chronic lung lesions and the independent variables of interest (serum 3MI concentration, BRSV antibody concentrations at the time of feedlot arrival, and treatment group) may have been partially the result of beef production practices of the Ohio Department of Rehabilitation and Correction. Their main objective is to provide a continuous and economic supply of beef for consumption by the state's inmate population. Therefore, many cattle participating in this study were not fed to maintain optimal growth rates after leaving the initial feedlot. The effect that these production practices had on the outcomes of this study is unknown.

[a]Ohio Department of Rehabilitation and Correction, Columbus, Ohio.
[b]Synshield, Grand Laboratories Inc, Larchwood, Iowa.
[c]Bovishield 4 + L5, Pfizer Inc, Animal Health Group, Exton, Pa.
[d]Micotil 300, Elanco Animal Health, Indianapolis, Ind.
[e]Nuflor, Schering-Plough Animal Health Corporation, Union, NJ.
[f]Animal Disease Diagnostic Laboratory, Ohio Department of Agriculture, Reynoldsburg, Ohio.
[g]SAS version 6.12, SAS Institute Inc, Cary, NC.

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