Associations between infectious bovine keratoconjunctivitis at weaning and ultrasongraphically measured body composition traits in yearling cattle

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Objective—To assess associations between infectious bovine keratoconjunctivitis (IBK) diagnosed at weaning and production traits in yearling beef calves.

Design—Retrospective population-based cohort study.

Animals—1,882 Angus calves.

Procedures—Angus calves from 1 farm were evaluated over 7 years. The association between yearling body production traits and detection of IBK lesions at weaning was evaluated.

Results—Yearlings that had evidence of IBK at weaning had less 12th rib fat depth, ribeye area, and body weight than did cohorts without evidence of IBK. Average daily gain was greater in cattle that had IBK lesions at weaning, but this did not offset lower body weight at weaning.

Conclusions and Clinical Relevance—The associations between IBK at weaning and production variables persisted well into the postweaning period, and there appeared to be a relationship between decreased body composition traits at yearling evaluation and IBK infection before weaning. (*J Am Vet Med Assoc* 2014;244:100–106)

Infectious bovine keratoconjunctivitis, commonly referred to as pinkeye, is one of the most important ocular diseases in cattle worldwide.[1] *Moraxella bovis* is widely considered to be the primary causative agent of IBK, although other organisms have been mentioned as possible causative agents.[2] Although cattle of all ages can be affected by IBK, most cases occur in cattle between 2 and 12 months of age. Cattle with IBK have clinical signs that include lacrimation, photophobia, corneal edema, ocular pain, and corneal ulceration. Although most cattle recover from IBK without serious sequelae, corneal scarring and vision loss can be permanent sequelae to acute infection.[3] Infectious bovine keratoconjunctivitis lesions have been associated with mean weaning weight losses of 17 kg (37.4 lb) in bulls and 18 kg (39.6 lb) in heifers in a 1974 study[4] as well as a mean 31-kg (68.2-lb) loss for the 365-day adjusted weight in the bulls that continued on a feed trial. More recently, a randomized and masked field trial[5] found mean losses at weaning in spring of 8.2 kg (18.04 lb; 95% CI, 4.04 to 12.52 kg [8.89 to 27.54 lb]).

Animal suffering and decreased weaning weight associated with IBK are likely the most important motivators for adoption of management practices to control IBK. However, it is unclear whether the production losses reported at weaning carry over to the postweaning production stage. Evidence that losses from IBK carry over to the postweaning periods would imply that cattle with evidence of IBK such as corneal scarring might reasonably be discounted at sale, further increasing the economic cost of IBK to producers. Alternatively, if the losses that occur before weaning are regained after weaning, perhaps because of the phenomenon of compensatory gain, discounting the value of calves with IBK lesions would not be necessary. Further, evidence that IBK could affect yearling trait measurements would imply that IBK could have influence on replacement selection decisions. Therefore, the aim of the study reported here was to examine whether the occurrence of IBK before weaning was associated with differences in production traits measured in yearlings for breed improvement purposes in cattle.

Abbreviations	
ADG	Average daily gain
IBK	Infectious bovine keratoconjunctivitis

Materials and Methods

Population and measured body composition traits—The study population was the Iowa State University Angus selection project calves reared at the Rhodes Research and Demonstration Farm in Marshall County, Iowa, from 2003 to 2004, and at the McNay Research and Demonstration Farm located in Lucas

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County, Iowa, from 2005 to 2009. The Iowa State University Institutional Animal Care and Use Committee approved the use of animals for the collection of data used in this study. This university-owned research herd consisted of approximately 250 to 300 spring-calving cows and 100 to 140 fall-calving cows after the move of the cow herd to the McNay Research and Demonstration Farm in 2005. The herd had a history of recurring IBK outbreaks, where an outbreak is arbitrarily defined as IBK occurrence in > 15% of calves prior to weaning. Cattle in this herd were maintained on pasture prior to weaning. Depending on the availability of pasture, calves were weaned at 3 to 6 months of age, with earlier weaning implemented in the fall calving season.

Spring and fall calves born on the farm from spring 2003 to spring 2009 and fall 2005 to fall 2008 were eligible for inclusion in the study. Birth weight, birth date, and sex were recorded at parturition by farm staff. Calves were observed for IBK and treated by farm staff prior to weaning. At weaning, calves were evaluated for presence and severity of IBK lesions (active or scar) in each eye.[6] For this study, calves were considered IBK affected if there was evidence of IBK in either eye; they were considered IBK negative if both corneas were apparently free of IBK infection. Observation for IBK ceased after weaning when calves were either selected as replacement cattle or sent to different feedlot facilities. Because this population was also used to characterize genetic susceptibility to IBK, no specific IBK preventive measures were used from 2003 to 2007.[6] In 2008 and 2009, 2 randomized masked clinical trials[5,7] assessed an IBK vaccine in the spring-born calves only; the vaccines were ineffective.

After weaning, the study calves were separated for management by sex. All heifers were developed as potential replacement heifers. After weaning, in each calving season, approximately half the bulls were castrated and the remaining half were retained for evaluation as potential replacement sires. Bull and steer cohorts were fed a similar diet after weaning.

Body composition traits were evaluated at appropriate times for yearling measurements reported to the American Angus Association breed improvement program (bulls, approx 365 days of age; steers, approx 390 days of age; and heifers, approx 390 days of age). Ultrasonographic images were collected by an Ultrasound Guidelines Council–certified field technician.[a] Ultrasonographic images were digitized and stored.[b] Ultrasound Guidelines Council–certified laboratory technicians later interpreted the images. The ultrasonographic body composition traits measured in the yearlings were as follows: subcutaneous fat thickness over the termination point of the biceps femoris in the rump, subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs, longissimus muscle area between the 12th and 13th ribs, and percentage of intramuscular fat within the longissimus muscle between the 12th and 13th ribs. Live weight was determined at the time ultrasonographic measurements were obtained (feed was withheld until after scanning on that day).

Sample size—Because the study was a population-based cohort study, the number of calves included in the analyses was determined by the number of calves born from 2003 to 2009 with complete records. However, prior to conducting the analysis, sample size calculations were performed to determine whether it was likely to obtain a data set of sufficient size to detect a difference of 7.5 kg (16.5 lb) in the primary outcome, live weight, in a population with 33% of calves in the IBK group and 67% in the unaffected group, with a type I error probability of 0.05, a type II error probability of 0.8, and a 1:2 ratio for case and control calves.[c] The rationale for use of these parameters was that results of a prior study[5] suggested that calves with IBK weighed approximately 7.5 kg less at weaning than unaffected calves, and the prevalence of IBK was approximately 33% in the study herd. Results of the analysis indicated that a study of approximately 1,000 subjects would have sufficient power to detect a 7.5-kg difference in live weight. The final study population contained 1,514 spring-born calves and 368 fall-born calves.

Study variables—Only calves with complete records for all weight categories (birth, weaning, and yearling), sex, and body composition traits were included in the analyses. Incomplete records were removed from the data set. Calves had incomplete records for several reasons: died prior to weaning, died following weaning, data were not collected at one of the time periods (birth, weaning, or yearling), and unrealistic data. Unrealistic data entries were birth weights > 200 kg (440 lb) or weaning weights > 500 kg (1,100 lb).

The final data set contained several categorical variables. Infectious bovine keratoconjunctivitis status was designated as positive or negative. After weaning, sex of calves was categorized as bull, heifer, or steer. Season (spring and fall), preweaning management group, postweaning management group, year, and sire were considered categorical variables. Continuous variables included all measured body composition traits in yearlings (live weight at scan, subcutaneous fat thickness over the termination point of the biceps femoris in the rump, subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs, longissimus muscle area between the 12th and 13th ribs, and percentage of intramuscular fat in the longissimus muscle between the 12th and 13th ribs), ADG, age of calf in days at ultrasonographic evaluation, and birth weight. Average daily gain was calculated over the period from weaning to evaluation as a yearling.

Statistical analysis—For descriptive purposes, the mean and SD were calculated for most variables. To determine how well the mean and SD represented the distribution of the data, the 95% confidence intervals of the mean and SD were compared with the 2.5% and 97.5% percentiles. For season, year, and case status (variables for which the difference was > 10% in > 3 instances), further descriptive information (median, 2.5% and 97.5% percentiles, mean, and SD) was provided.

For hypothesis testing, the unit of interest was the individual calf. A linear regression mixed model with fixed and random effects was used to test the hypotheses about the associations between IBK and yearling body production traits.[d] Performance and ultrasonographic body composition traits evaluated were live weight at scan, subcutaneous fat thickness over the termination point of the biceps femoris in the rump, subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs, longissimus muscle area between the 12th and 13th ribs, percentage of intramuscular fat in the longissimus muscle between the 12th and 13th ribs, and ADG. All models were created for spring-born calves, fall-born calves, and the combined population. In each model, the explanatory variable of interest was IBK status. Other explanatory variables included in each model as potential effect modifiers or confounders of the association between IBK and weight at ultrasonographic evaluation were birth weight, season, sex of calves after weaning (bull, heifer, or steer), ADG (weaning to yearling weight), preweaning management group, postweaning management group, year of calving, season of calving, the interaction between year and season, and age at ultrasonographic evaluation. Those explanatory variables included as fixed effects were ADG, weight at birth, sex of calves after weaning (bull, heifer, or steer), age, the interaction of sex of calves after weaning (bull, heifer, or steer) and age at time of ultrasonography, and season. Those explanatory variables included as random effects were preweaning management group, postweaning management group, year, and sire as well as the interaction of year and season. Continuous variables were not transformed. Variable elimination techniques were not used; associations were determined from the full-adjusted final model. A model was also created with ADG as the outcome. The model building process was as described; however, ADG was not included as an explanatory variable because it was the outcome of interest.

The associations for the production traits and IBK status were reported as the least squares mean for each production trait, SEM, and *P* value. For the random effects, the variance component estimate was reported.

For each outcome, the fit of the full-adjusted final model was assessed for conformity by observation of each model's graphed deviance residuals and Pearson residuals against the independent variables. Collinearity of fixed effect variables was assessed after removing the random effects and rerunning the model. The condition indices and variance decompositions were calculated with a macroinstruction generated for statistical software.[d] Collinearity was considered present if the largest condition index was > 30 and at least 2 of the variance decomposition proportions were ≥ 0.5. If evidence of collinearity was identified, the variables with the high variance decompositions would be removed from the model. A value of $P \leq 0.05$ was considered significant.

Results

A total of 2,462 calves were born between spring 2003 and spring 2009 on the McNay Research and Demonstration Farm. Five hundred eighty calves were removed prior to analysis because of incomplete records. The primary reason for removal was lack of IBK status at weaning, which included all data from fall 2006. A total of 1,882 records were used in the final analysis. Variables of interest by season and year for calves by IBK status were descriptively analyzed (**Tables 1–3**). Extended descriptive statistics were required because of low numbers for all fall cases of IBK and for the variable subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs.

For each outcome, the results of the mixed model analysis were summarized (Table 3). There was some indication that the associations between IBK and production variables was different in fall-born calves versus spring-born calves; therefore, results for all 3 models are given. However, the discussion is limited to spring-born calves because the fall-born population was small and therefore the estimates of association were imprecise. The data from the fall-born calves are given be-

Table 1—Mean ± SD values for production variables in yearling calves born in spring 2003 to 2009 that had or did not have IBK lesions at weaning.

				Ultrasonographic measurements			
Year	Group	Weaning weight (kg)	ADG (kg/d)	Rump fat thickness (cm)	LMA (cm²)	LMA fat percentage	Live weight (kg)
2003	Affected (n = 142)	199 ± 40	1.15 ± 0.27	0.70 ± 0.21	75.57 ± 8.79	5.02 ± 1.58	436.79 ± 63.58
	Unaffected (n = 141)	214 ± 35	1.11 ± 0.30	0.69 ± 0.22	74.68 ± 9.24	4.67 ± 1.48	428.22 ± 67.92
2004	Affected (n = 81)	207 ± 29	1.15 ± 0.33	0.74 ± 0.19	72.91 ± 11.63	4.70 ± 1.31	432.47 ± 72.25
	Unaffected (n = 116)	222 ± 29	1.13 ± 0.36	0.72 ± 0.18	74.33 ± 11.20	4.72 ± 1.12	440.68 ± 77.21
2005	Affected (n = 76)	180 ± 31	1.08 ± 0.24	0.68 ± 0.20	63.33 ± 8.84	4.76 ± 1.57	396.14 ± 60.29
	Unaffected (n = 122)	202 ± 26	1.07 ± 0.20	0.73 ± 0.21	66.46 ± 7.52	4.18 ± 1.55	404.81 ± 41.03
2006	Affected (n = 118)	178 ± 30	1.04 ± 0.35	0.70 ± 0.20	63.43 ± 9.40	5.18 ± 1.35	400.15 ± 69.55
	Unaffected (n = 85)	185 ± 24	1.05 ± 0.35	0.71 ± 0.19	64.30 ± 9.83	4.72 ± 1.18	405.73 ± 69.46
2007	Affected (n = 71)	188 ± 35	1.06 ± 0.31	0.60 ± 0.20	60.67 ± 10.74	4.91 ± 1.15	397.13 ± 66.27
	Unaffected (n = 124)	193 ± 28	0.98 ± 0.31	0.60 ± 0.19	59.45 ± 11.22	4.91 ± 1.23	386.50 ± 68.3
2008	Affected (n = 77)	138 ± 27	1.05 ± 0.40	0.65 ± 0.20	62.80 ± 15.87	5.45 ± 1.39	377.46 ± 85.39
	Unaffected (n = 139)	154 ± 24	1.07 ± 0.39	0.73 ± 0.23	64.25 ± 15.16	5.09 ± 1.13	394.74 ± 80.24
2009	Affected (n = 85)	167 ± 31	0.98 ± 0.34	0.62 ± 0.19	61.91 ± 12.11	5.04 ± 1.28	381.65 ± 72.62
	Unaffected (n = 137)	181 ± 29	0.99 ± 0.37	0.69 ± 0.21	64.35 ± 12.06	4.89 ± 1.18	396.97 ± 73.29
Total	Affected (n = 650)	181 ± 38	1.08 ± 0.32	0.68 ± 0.20	66.68 ± 12.39	5.02 ± 1.41	406.28 ± 72.93
	Unaffected (n = 864)	192 ± 35	1.06 ± 0.33	0.70 ± 0.21	66.94 ± 12.39	4.75 ± 1.31	408.04 ± 71.53

Feed was withheld until after scanning.

LMA = Longissimus muscle area between the 12th and 13th ribs. LMA fat percentage = Subcutaneous fat percentage at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs. Rump fat thickness = Subcutaneous fat thickness over the termination point of the biceps femoris in the rump.

Table 2—Descriptive statistics for yearling calves born in fall 2005 to 2008 that had or did not have IBK lesions at weaning.

Year	Group	Descriptive statistic	Weaning weight (kg)	ADG (kg/d)	Ultrasonographic measurements: Rump fat thickness (cm)	Ultrasonographic measurements: LMA (cm^2)	Ultrasonographic measurements: LMA fat percentage (%)	Live weight (kg)
2005	Affected (n = 15)	Median	109	1.09	0.56	63	3.99	376
		95% CI	81–148	0.47–1.47	0.16–1.31	32–79	3.16–6.07	213–494
		Range	73–150	0.46–1.47	0.15–1.37	32–79	3.08–6.11	211–495
		Mean ± SD	115 ± 22	0.92 ± 0.37	0.58 ± 0.38	55 ± 18	4.46 ± 1.02	344 ± 99
	Unaffected (n = 92)	Mean ± SD	134 ± 23	1.01 ± 0.40	0.66 ± 0.34	60 ± 16	4.55 ± 1.15	383 ± 101
2007	Affected (n = 9)	Median	141	0.64	0.64	54	4.13	333
		95% CI	89–185	0.44–1.66	0.12–1.11	35–92	3.24–6.21	219–562
		Range	88–191	0.44–1.69	0.12–1.12	34–93	3.18–6.65	209–564
		Mean ± SD	135 ± 35	0.98 ± 0.55	0.59 ± 0.42	60 ± 22	4.27 ± 0.99	380 ± 140
	Unaffected (n = 123)	Mean ± SD	144 ± 24	0.98 ± 0.49	0.65 ± 0.39	61 ± 18	4.55 ± 0.98	382 ± 117
2008	Affected (n = 3)	Median	122	0.57	0.48	43	4.63	295
		Range	120–141	0.50–1.21	0.41–1.22	43–74	4.20–4.83	274–493
	Unaffected (n = 126)	Mean ± SD	126 ± 23	1.02 ± 0.37	0.71 ± 0.29	66 ± 18	4.76 ± 1.15	407 ± 97
Total	Affected (n = 27)	Median	120	0.66	0.56	54.18	4.20	333
		95% CI	83–171	0.45–1.61	0.13–1.27	32.25–89.53	3.15–6.30	210–558
		Range	73–191	0.44–1.69	0.10–1.37	32.25–92.88	3.08–6.65	209–564
		Mean ± SD	123 ± 27	0.92 ± 0.42	0.59 ± 0.39	56.50 ± 18.79	4.41 ± 0.94	357 ± 113
	Unaffected (n = 341)	Mean ± SD	135 ± 25	1.00 ± 0.42	0.67 ± 0.34	62.43 ± 17.75	4.63 ± 1.09	391 ± 106

See Table 1 for key.

Table 3—Descriptive statistics for subcutaneous fat thickness (cm) at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs in yearling calves born in spring 2003 to 2009 or fall 2005, 2007, and 2008 that had or did not have IBK lesions at weaning.

Variable	2003	2004	2005	2006	2007	2008	2009	Total
Spring								
Affected								
No. of cows	142	81	76	118	71	77	85	650
Median	0.76	0.69	0.61	0.69	0.51	0.61	0.53	0.69
95% CI	0.48–1.19	0.36–1.04	0.29–1.08	0.33–1.08	0.27–1.13	0.28–1.22	0.25–1.17	0.28–1.17
Range	0.36–1.40	0.28–1.32	0.25–1.19	0.23–1.35	0.25–1.19	0.20–1.30	0.23–1.30	0.20–1.40
Mean ± SD	0.79 ± 0.20	0.69 ± 0.18	0.64 ± 0.22	0.69 ± 0.20	0.57 ± 0.24	0.64 ± 0.25	0.63 ± 0.29	0.68 ± 0.23
Unaffected								
No. of cows	141	116	122	85	124	139	137	864
Median	0.76	0.66	0.64	0.69	0.53	0.71	0.64	0.66
95% CI	0.45–1.15	0.38–1.00	0.30–1.17	0.36–1.07	0.30–1.04	0.25–1.19	0.28–1.31	0.28–1.17
Range	0.38–1.73	0.28–1.17	0.28–1.35	0.33–1.12	0.23–1.09	0.20–1.47	0.23–1.70	0.201.73
Mean ± SD	0.76 ± 0.19	0.67 ± 0.17	0.67 ± 0.22	0.69 ± 0.19	0.56 ± 0.19	0.69 ± 0.26	0.68 ± 0.30	0.68 ± 0.23
Fall								
Affected								
No. of cows	—	—	15	—	9	3	—	27
Median	—	—	0.51	—	0.48	0.43	—	0.48
95% CI	—	—	0.13–1.12	—	0.13–1.21	0.41–0.99	—	0.13–1.19
Range	—	—	0.13–1.14	—	0.13–1.27	0.41–1.02	—	0.13–1.27
Mean ± SD	—	—	0.53 ± 0.36	—	0.54 ± 0.43	0.62 ± 0.35	—	0.55 ± 0.37
Unaffected								
No. of cows	—	—	92	—	123	126	—	341
Median	—	—	0.59	—	0.53	0.65	—	0.61
95% CI	—	—	0.14–1.46	—	0.13–1.35	0.18–1.21	—	0.14–1.39
Range	—	—	0.1–1.6	—	0.1–1.65	0.13–1.6	—	0.1–1.65
Mean ± SD	—	—	0.61 ± 0.38	—	0.59 ± 0.35	0.65 ± 0.31	—	0.62 ± 0.34

— = Not applicable.

cause they may be useful in a subsequent meta-analysis or cost-benefit analysis.

For the spring-born calves only, IBK status prior to weaning was significantly associated with decreased performance for live weight at the time of scanning (mean difference, –6.73 kg [14.81 lb]), subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs (mean difference, –0.02 cm), and longissimus muscle area between the 12th and 13th ribs (mean difference, –1.12 cm^2). The point estimate for subcutaneous fat thickness over the termination point of the biceps femoris in the rump indicated an association with IBK status (difference, –0.019), although the confidence interval for this trait included the null value ($P = 0.065$). The association between postweaning ADG and IBK status was positive (difference, 0.02 kg/d [0.044 lb/d]; $P = 0.02$). This association indicated that IBK occurrence prior to weaning was associated with greater postweaning ADG.

For the combined data set (spring and fall calves), the associations observed were similar to those observed in spring-born calves because spring-born calves contributed most of the data to the combined analysis. The occurrence of IBK prior to weaning was significantly associated with decreased performance for live weight at the time of scanning (difference, –7.02 kg [15.44 lb]), subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs (difference, –0.02 cm), and longissimus muscle area between the 12th and 13th ribs (difference, –1.14 cm^2; **Table 4**). Subcutaneous fat thickness over the termination point of the biceps femoris in the rump in calves with IBK was less than that in calves without IBK (mean difference, –0.019), but this did not quite reach significance ($P = 0.06$). The association between postweaning ADG and IBK occurrence prior to weaning was positive (difference, 0.02 kg/d; $P = 0.01$). This association indicated that IBK occurrence was associated with greater postweaning ADG.

The random effects variance components estimates (an estimate of the variance attributable to that random variable on the trait of interest) for each model were summarized (**Table 5**). When plots of the residuals versus means were examined, no points were found to be outliers and the patterns of residual distribution were consistent with normal assumptions. Collinearity was assessed on models with the random effects removed. All condition indexes were < 30 and variance decompositions were < 0.5.

Table 4—Least square mean ± SEM values and *P* values for associations between IBK and production variables in 1,882 yearling calves that had or did not have IBK lesions at weaning.

	Combined		Fall		Spring		*P* value		
Variable	**Affected**	**Unaffected**	**Affected**	**Unaffected**	**Affected**	**Unaffected**	**Combined**	**Fall**	**Spring**
ADG (kg/d)*	1.12 ± 0.06	1.10 ± 0.06	1.10 ± 0.09	1.10 ± 0.09	1.14 ± 0.02	1.12 ± 0.02	< 0.01	0.81	0.02
Ultrasonographic measurements									
Rump fat thickness (cm)†	0.69 ± 0.09	0.71 ± 0.09	0.74 ± 0.10	0.76 ± 0.09	0.67 ± 0.05	0.70 ± 0.49	0.06	0.06	0.07
12th rib fat thickness (cm)†	0.64 ± 0.05	0.66 ± 0.05	0.66 ± 0.06	0.68 ± 0.05	0.65 ± 0.04	0.67 ± 0.04	0.02	0.05	0.03
LMA (cm^2)†	64.47 ± 2.41	65.64 ± 2.41	61.11 ± 2.86	63.46 ± 2.66	66.08 ± 1.69	67.20 ± 1.68	< 0.01	0.04	0.02
LMA fat percentage (%)†	4.83 ± 0.18	4.78 ± 0.18	4.32 ± 0.28	4.69 ± 0.22	4.97 ± 0.17	4.90 ± 0.17	0.37	0.07	0.20
Live weight (kg)†	397.12 ± 9.47	404.13 ± 9.44	381.31 ± 7.99	391.93 ± 7.23	401.29 ± 5.63	408.02 ± 5.62	< 0.01	< 0.01	< 0.01

*Fixed effects included weight at birth, sex of IBK-affected calves after weaning (bull, heifer, or steer), days alive, the interaction between sex of IBK-affected calves after weaning (bull, heifer, or steer) and days alive, and season. †Fixed effects included postweaning ADG of IBK-affected calves, weight at birth, sex of IBK-affected calves after weaning (bull, heifer, or steer), days alive, the interaction between sex of IBK-affected calves after weaning (bull, heifer, or steer) and days alive, and season.

12th rib fat thickness = Subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs.

See Table 1 for remainder of key.

Table 5—Estimate of variances for random effects in the model for each of the traits of interest in a study of the associations between IBK and production variables in 1,882 yearling calves that had or did not have IBK lesions at weaning.

Variable	**Rump fat thickness (cm)**	**12th rib fat thickness (cm)**	**LMA (cm^2)**	**Live weight (kg)**	**LMA fat percentage (%)**	**ADG (kg/d)**
Overall						
Sire	0.00	0.00	0.44	10.34	0.19	0.0009
Year	0.00	0	0	0	0	0
Year X season interaction	0	0.00	1.71	51.72	0.03	0.00
Preweaning management group	0.00	0.00	0.55	155.28	0.00	0.00
Postweaning management group (IBK affected)	0.05	0.01	3.99	457.84	0.12	0.02
Residual	0.03	0.03	5.99	400.18	1.11	0.02
Total	0.09	0.05	12.70	1075.37	1.49	0.04
Fall						
Sire	0.01	0.00	2.23	12.35	0.081	0.00
Year	0	0.00	11.57	33.85	0.017	0.00
Preweaning management group	0.00	0.00	0	33.61	0.055	0.00
Postweaning management group (IBK affected)	0.03	0.00	11.63	131.5	0.078	0.02
Residual	0.04	0.29	30.16	301.08	0.83	0.01
Total	0.07	0.31	55.59	512.39	1.07	0.042
Spring						
Sire	0.00	0.00	2.78	11.28	0.19	0.00
Year	0.00	0.00	12.58	67.74	0.03	0.00
Preweaning management group	0.00	0.00	3.50	179.85	0	0.00
Postweaning management group (IBK affected)	0.01	0.00	3.87	58.74	0.10	0.00
Residual	0.03	0.023	40.33	417.76	1.17	0.02
Total	0.05	0.04	63.07	735.37	1.49	0.03

See Tables 1 and 4 for key.

Discussion

Traditionally, IBK has been thought of as a preweaning production issue (ie, losses associated with IBK were temporary and recovered after weaning). The objective of this study was to examine whether the occurrence of IBK before weaning was associated with production traits following weaning in seedstock. Results indicated that evidence of IBK infection observed at weaning were associated with postweaning production and replacement animal selection traits. Therefore, calves with evidence of IBK such as corneal scarring might reasonably be discounted at sale because they are likely to continue to weigh less than unaffected calves. This finding further increases the potential economic cost of IBK to the cattle industry. For producers who retain ownership of such calves, losses to production from IBK continue as calves approach slaughter weight. Prevention of IBK is the most effective method of mitigating losses from IBK.

Although calves with IBK in this study had a higher ADG after weaning, it was not sufficient to make up the losses in live weight sustained prior to weaning. Spring-born calves with IBK had an ADG a mean of 0.02 kg/d greater after weaning than unaffected contemporary calves; however, calves with IBK were a mean of 7 kg (15.4 lb) lighter than unaffected calves at the time of yearling measurement (95% CI, –5 to –9 kg [11 to 19.8 lb]). For fall-born calves, the estimate was approximately 11 kg (24.2 lb) less weight at evaluation for IBK-affected calves, however, this estimate, based on a much smaller population, had a greater degree of uncertainty (95% CI, –4 to –18 kg [8.8 to 39.6 lb]). Similarly, IBK-affected calves were associated with decreased rib fat depth (subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs) and ribeye area (longissimus muscle area between the 12th and 13th ribs), compared with unaffected calves. The results therefore have implications for producers buying or selling yearling calves for seedstock. These producers may underestimate the genetic value of an animal due to decreased values for live weight, subcutaneous fat thickness at three-fourths the lateral distance across the longissimus muscle between the 12th and 13th ribs, or longissimus muscle area between the 12th and 13th ribs. However, IBK occurrence rather than genetic potential might be the cause of decreased values. For seedstock producers with herds with a high incidence of IBK, this is likely to have the greatest effect. Presently, prevention of IBK is extremely difficult, with little evidence that IBK vaccines are effective.[8] High standards of animal husbandry and well-being should already be the strongest motivator for rapid identification and treatment of IBK lesions; however, knowledge that losses can extend beyond the weaning period may provide additional incentive to quickly intervene and reduce losses associated with IBK.

In this study, ultrasonographic measurements were used to evaluate performance traits after weaning. Additionally, ultrasonographic evaluations were taken at yearling time under a management system for developing replacement breeding stock in a selection project. The management system may not represent the typical birth-to-slaughter system and not reflect the full effects of (or possible recovery from) IBK if calves were allowed to continue to slaughter. The rationale for use of these ultrasonography-based measures of production rather than measurements made on calves at slaughter was 2-fold. First, a portion of the population was selected as herd replacements, allowing us to gather information on replacement stock. Carcass data were only available on animals that were not selected, which would not represent the whole population of a typical herd. Use of this population permitted an increase in the ability to detect differences in affected animals that are used as seedstock (replacement stock). Second, because we used most of the population, we reduced the potential for selection bias caused by loss to follow-up of poor doers, a common source of bias in population-based cohort studies. If we had only studied the population of slaughtered calves, > 60% of the female population and approximately 5% of the male population may have been lost to follow-up and the degree of bias could have been considerable but the direction of bias unknown.[9]

The association between IBK and carcass traits is obviously of interest, and it is tempting to extrapolate the results of this study to slaughtered cattle. Such extrapolation should be done with caution. First, a slaughter population is different from a seedstock population and this could introduce a bias in the estimated associations. Further, although studies by Greiner et al[10] and Tait et al[11] revealed that live animal ultrasonography results can be used to accurately assess animal carcass composition, the correlation declines the further from slaughter ultrasonography is conducted.

It would also be of interest to compare the results of the present study with other similar studies, but we are aware of only 1 study[4] of the long-term association between preweaning IBK and production. In 1974, Thrift and Overfield[4] reported a mean difference of 31 kg in 365-day adjusted weight in bull calves in a postweaning feed trial and a decrease in ADG of 0.08 kg (0.176 lb). The explanation for the different association observed for ADG between that study[4] and the present study is unknown; however, differences in management, having a bull-only population, or other unreported study characteristics are likely. Another study[12] found changes in production traits associated with treatment for any preweaning disease, including bovine respiratory disease, IBK, and infectious pododermatitis; however, the sole contribution of IBK to losses was not determined. Other studies[13–15] that evaluated disease occurrence and production traits have focused on postweaning disease, in particular, bovine respiratory disease. It may be surprising that few studies have evaluated the association between preweaning disease and postweaning production traits; however, few preweaning diseases are as readily diagnosed as IBK. One possible reason may be that diarrhea and respiratory tract disease prior to weaning are difficult to study in extensive pasture-based production systems. Further, following cattle from pasture to the feedlot can be difficult in the North American production system, where ownership frequently changes, which makes longitudinal studies difficult to execute.

Data from this study were obtained from 1 farm over 7 years and included 1,882 complete records and 672 cases of IBK. The pathogenesis and host response

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to IBK are likely similar in all cattle populations. Although environment and management practices differ between farms and likely modify factors such as the prevalence and duration of IBK, it is most likely that the observed associations of decreased fat deposits, ribeye area, and overall weight in affected calves are consistent, although the magnitude may differ.

As with any observational study, the potential for confounding bias, misinformation bias, and selection bias is greater than occurs in experimental studies, and methods to reduce bias should be addressed.[9] We addressed confounding bias at the analysis stage by inclusion of potential confounding variables in the final model. The most important confounder missing from the study was the status of other diseases in the herd. We hypothesize that calves with IBK may be more susceptible to other diseases, which would negatively affect the calf's ability to add muscle, fat, and overall body weight. If this hypothesis is correct, other diseases may have contributed to the associations we attributed to IBK, so the true effects of IBK may have been less than the estimates of this study.

Misinformation bias might have occurred for the explanatory variable of interest, IBK. Because IBK assessments at weaning were used, the most likely bias was incorrect classification of calves with IBK lesions before weaning as not having IBK lesions at weaning (ie, a false negative). This misclassification would occur if calves had IBK lesions that resolved quickly and without scars and went undetected. Further, treatment prior to weaning could result in fewer scars. Such misinformation bias is likely not differential, and therefore, the direction of bias should be toward the null. Consequently, estimates of the association between IBK lesions and production traits in this study would be conservative.

Another potential form of bias in observational studies is selection bias, which cohort studies are susceptible to because of loss to follow-up. In this study, a major source of selection bias was minimized by studying the population at the time yearling ultrasonographic measurements were made rather than studying slaughtered calves. Another selection bias could occur if incomplete records were associated with a combination of IBK occurrence and one of the outcomes (ie, if IBK-affected calves with low scanning weights were more likely to have incomplete reports than IBK-affected calves with higher scanning weights). If such a selection bias did exist, we hypothesize that it was most likely that lightweight calves (which would go on to be lightweight at ultrasonographic evaluation) could be more susceptible to IBK and also more susceptible to other life-threatening infections. The resulting bias would be that the IBK-affected calves included in the final analysis would be heavier than the true population of IBK-affected calves. As such, the study would again be biased toward the null, and therefore, the estimates of the association between IBK lesions and production outcomes would be conservative.[9] Thirteen percent of records were lost to follow-up, and the remaining 87% of the population was in the acceptable range for loss to follow-up given enough data to maintain study validity.[16]

The present study found significant associations between IBK and production traits evaluated in yearling calves. The mechanism of the residual weight loss was unclear because the study was not designed to determine mechanisms of pathogenesis, but rather to determine whether differences between groups did occur. The use of production traits to detect the losses associated with preweaning IBK may be of greater value than previously suspected in making selection decisions in seedstock herds. The value of disease avoidance or rapid diagnosis and treatment of IBK may be increased when cattle are sold on the basis of production traits because of the negative associations between IBK and certain production traits.

a. Classic Scanner 200 with ASP-18 transducer, Classic Medical, Tequesta, Fla.
b. BlackBox Image Capturing System, Biotronics Inc, Ames, Iowa.
c. PS, version 3.0, Vanderbilt Biostatistics. Available at: biostat.mc.vanderbilt.edu/twiki/bin/view/Main/PowerSampleSize. Accessed Jun 1, 2010.
d. PROC MIXED, SAS, version 9.3, SAS Institute Inc, Cary, NC.

References

1. Baptista PJ. Infectious bovine keratoconjunctivitis: a review. *Br Vet J* 1979;135:225–242.
2. Angelos JA. *Moraxella bovoculi* and infectious bovine keratoconjunctivitis: cause or coincidence? *Vet Clin North Am Food Anim Pract* 2010;26:73–78.
3. Brown MH, Brightman AH, Fenwick BW, et al. Infectious bovine keratoconjunctivitis: a review. *J Vet Intern Med* 1998;12:259–266.
4. Thrift FA, Overfield JR. Impact of pinkeye (infectious bovine kerato-conjunctivitis) on weaning and postweaning performance of Hereford calves. *J Anim Sci* 1974;38:1179–1184.
5. Funk L, O'Connor AM, Maroney M, et al. A randomized and blinded field trial to assess the efficacy of an autogenous vaccine to prevent naturally occurring infectious bovine keratoconjunctivis (IBK) in beef calves. *Vaccine* 2009;27:4585–4590.
6. Kizilkaya K, Tait RG, Garrick DJ, et al. Whole genome analysis of infectious bovine keratoconjunctivitis in Angus cattle using Bayesian threshold models. *BMC Proc* 2011;5(suppl 4):S22.
7. O'Connor AM, Brace S, Gould S, et al. A randomized clinical trial evaluating a farm-of-origin autogenous *Moraxella bovis* vaccine to control infectious bovine keratoconjunctivis (pinkeye) in beef cattle. *J Vet Intern Med* 2011;25:1447–1453.
8. Burns MJ, O'Connor AM. Assessment of methodological quality and sources of variation in the magnitude of vaccine efficacy: a systematic review of studies from 1960 to 2005 reporting immunization with *Moraxella bovis* vaccines in young cattle. *Vaccine* 2008;26:144–152.
9. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61:344–349.
10. Greiner SP, Rouse GH, Wilson DE, et al. Prediction of retail product weight and percentage using ultrasound and carcass measurements in beef cattle. *J Anim Sci* 2003;81:1736–1742.
11. Tait RG Jr, Wilson DE, Rouse GH. Prediction of retail product and trimmable fat yields from the four primal cuts in beef cattle using ultrasound or carcass data. *J Anim Sci* 2005;83:1353–1360.
12. Garcia MD, Thallman RM, Wheeler TL, et al. Effect of bovine respiratory disease and overall pathogenic disease incidence on carcass traits. *J Anim Sci* 2010;88:491–496.
13. Gardner BA, Dolezal HG, Bryant LK, et al. Health of finishing steers: effects on performance, carcass traits, and meat tenderness. *J Anim Sci* 1999;77:3168–3175.
14. Reinhardt CD, Busby WD, Corah LR. Relationship of various incoming cattle traits with feedlot performance and carcass traits. *J Anim Sci* 2009;87:3030–3042.
15. Schneider MJ, Tait RG Jr, Busby WD, et al. An evaluation of bovine respiratory disease complex in feedlot cattle: impact on performance and carcass traits using treatment records and lung lesion scores. *J Anim Sci* 2009;87:1821–1827.
16. Kristman V, Manno M, Cote P. Loss to follow-up in cohort studies: how much is too much? *Eur J Epidemiol* 2004;19:751–760.