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Effect of bovine respiratory disease and overall pathogenic disease incidence on carcass traits[1,2]

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ABSTRACT: The objective this study was to evaluate the effects of incidence of bovine respiratory disease (BRD) and overall incidence of pathogenic diseases (IPD) on carcass traits. Two independent populations were used. The first population included crossbred steers (GPE7; n = 642) derived from sires of 7 *Bos taurus* breeds: Angus, Charolais, Gelbvieh, Hereford, Limousin, Red Angus, and Simmental. The second population included crossbred steers (GPE8; n = 621) derived from tropically adapted *Bos taurus* breeds and *Bos indicus*-influenced breeds: Beefmaster, Brangus, Bonsmara, and Romosinuano, as well as Hereford and Angus. Treatment records for BRD, infectious keratoconjunctivitis, and infectious pododermatitis were available for these populations. Incidence of BRD was treated as an independent effect. Incidences of the 3 microbial pathogenic diseases were pooled into a single trait to represent overall pathogenic disease incidence. Traits evaluated were HCW; KPH; LM area; marbling score; fat thickness; dressing percentage; yield grade; retail, fat, and bone yields; and meat tenderness. Both BRD and IPD were associated with differences in yield grade in GPE7 and GPE8 steers. Animals treated for BRD had decreased yield grades (P = 0.003 and P = 0.02, in GPE7 and GPE8, respectively) compared with untreated animals. Animals treated for IPD had decreased yield grades (P = 0.0006 and P = 0.004, in GPE7 and GPE8, respectively) compared with untreated animals. Incidence of BRD and IPD were associated with a reduction in fat thickness in GPE7 and GPE8 steers. Animals treated for BRD had reduced adjusted fat measurements (P = 0.0007 and P = 0.01, in GPE7 and GPE8) compared with untreated animals. Animals treated for IPD also had reduced adjusted fat measurements (P = 0.0003 and P = 0.002, in GPE7 and GPE8) compared with untreated animals. Animals treated for BRD ($P < 0.007$) or IPD ($P < 0.02$) in the GPE7 population also had decreased estimated KPH measurements compared with unaffected animals. Animals affected with BRD in GPE8 had greater ($P < 0.05$) shear force measurements than unaffected animals. Animals affected with IPD in GPE8 had greater HCW ($P < 0.03$) and fat yield ($P < 0.01$) measurements but lesser bone yield ($P < 0.03$) and retail product yield ($P < 0.01$) measurements than unaffected animals. The relationship between disease and carcass traits should be given consideration by future studies that aim to develop selection strategies based on specific traits.

Key words: beef cattle, carcass trait, shipping fever

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INTRODUCTION

Bovine respiratory disease (**BRD**) is the most economically important cattle disease in the United States. Estimates of costs associated with BRD, including treatment, prevention, morbidity, and mortality, have been reported to be approximately $13.90 per animal affected (Snowder et al., 2006). Animals typically develop symptoms of the disease during times of stress, when the immune system is compromised. These stress events include weaning, restraint, social reorganization, transport, and nutritional changes (Cole, 1996). Animals that become infected with BRD in these instances typically decrease nutrient (Galyean and Hubbert, 1995) and water intake (Buhman et al., 2000). Carcass composition and meat quality traits are most likely negatively affected (Gardner et al., 1999), magnifying the economic consequences of BRD. As evidence of this effect, previous studies have reported decreased marbling scores (Montgomery et al., 1984) in animals contracting BRD. Further, animals contracting BRD

[1]Mention of a trade name, a proprietary product, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

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during the production process have been reported to have decreased HCW and yield grades (Roeber et al., 2001). However, previous studies lacked background information, such as the management system in which the animals were raised and genetic background information.

Although management and selection strategies are currently being developed to deal with the negative economic impact of BRD, it is essential to understand the relationships between traits that are significantly affected by BRD and other infectious diseases. Therefore, the objective of the current study was to evaluate the effects BRD and other infectious diseases have on carcass traits in 2 independent populations of cattle with similar production management backgrounds.

MATERIALS AND METHODS

Experimental procedures were approved and performed in accordance with the US Meat Animal Research Center animal care guidelines and the Guide for Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999).

Animals

Two independent populations were used. The first population was *Bos taurus* and the second population included germplasm from *B. taurus* and *Bos indicus*. Cycle 7 of the Germplasm Evaluation project (**GPE7**) included 642 crossbred steers of *B. taurus* descent, constituting 7 sire breeds (Wheeler et al., 2005). Briefly, approximately equal numbers of calves were produced from 149 purebred sires representing the 7 most common beef breeds with the greatest number of annual registrations (Hereford, Angus, Red Angus, Simmental, Gelbvieh, Limousin, and Charolais). These purebred sires were mated to Angus, Hereford, or MARC III (composite of 1/4 Hereford, 1/4 Angus, 1/4 Pinzgauer, and 1/4 Red Poll) cows through AI. Calves were born between March and mid-April of 1999 and 2000. Male calves were castrated within 24 h of birth. Calves were creep fed from mid-July or early August until weaning in mid-October at an average age of 202 d. Specific management of cattle and collection of phenotypic data were reported by Wheeler et al. (2005).

Cycle 8 of the Germplasm Evaluation project (**GPE8**) included 621 crossbred steers. Briefly, approximately equal numbers of calves were produced from 127 purebred sires representing tropically adapted breeds, including Beefmaster, Brangus, Bonsmara, and Romosinuano, as well as Hereford and Angus for the intercycle Germplasm Evaluation standardization process. Sires were bred via AI to Angus or MARC III cows. Calves were born between March and mid-April of 2001 and 2002. Management of these animals and collection of phenotypes were similar to those for GPE7 animals (Wheeler et al., 2005).

Disease Detection

Cattle were monitored daily by a staff veterinarian, beef cattle research technicians, or both. Animals affected by disease were diagnosed by physical examination and information was recorded. However, no laboratory diagnostic techniques were used in the diagnosis of BRD in the current study. If an animal was found deceased, necropsy or laboratory analysis was conducted and results were recorded. Clinical symptoms that supported the diagnosis of BRD included fever, rapid breathing, repetitive coughing, nasal or eye discharge, diarrhea, dehydration, and appetite suppression (Snowder et al., 2007).

Overall incidence of pathogenic disease (**IPD**) was defined as diseases affecting cattle in these 2 populations, including BRD, infectious bovine keratoconjunctivitis (commonly known as pinkeye), and infectious pododermatitis (commonly known as footrot). These diseases were included because of the bacterial nature of their infections.

For analyses, calves diagnosed and treated for BRD or IPD were classified as affected by a microbial pathogenic disease and coded as "1." No distinction was made regarding whether the animal was treated multiple times for the same or different diseases. Animals not receiving any treatment were classified as unaffected and coded as "0." Affected animals were assumed to be less resistant to the causative pathogens of the 3 diseases. Incidences of the 3 microbial pathogenic diseases were pooled into a single binary trait to represent an overall IPD.

Traits Evaluated

Steers from GPE7 born in 1999 were slaughtered in 5 groups spanning a 43-d interval (May 15, June 11, June 12, June 25, and June 27, 2000). Steers born in 2000 were slaughtered in 4 groups spanning a 53-d interval (May 7, May 21, June 11, and June 25, 2001). Steers from GPE8 born in 2001 were slaughtered in 4 groups spanning a 36-d interval (May 13, May 20, June 10, and June 17, 2002). Steers from GPE8 born in 2002 were slaughtered in 4 groups spanning a 36-d interval (May 12, May 19, June 2, and June 16, 2003). All steers were slaughtered in commercial beef processing facilities. Slaughter procedures and fat-related carcass trait data for GPE7 and GPE8 steers were collected using the procedures described previously (Shackelford et al., 1995; Wheeler et al., 2005). Carcass traits included HCW (kg); adjusted fat thickness (cm); LM area (cm^2); yield grade; percentage of animals classified as choice; dressing percentage; KPH; marbling score; meat tenderness; and retail, fat, and bone yield. Marbling score was evaluated on a cross-section of the LM at the 12th to 13th rib as described in previous studies (USDA, 1997; Wheeler et al., 2005). Retail, fat, and bone yields were estimated using prediction equations that included carcass yield grade traits (LM area, adjusted fat thickness, and estimated KPH) and marbling score (Shackelford et al., 1995). Meat tenderness was measured as Warner-Bratzler shear force, and shear force data were collected on LM samples from steers at 14 d postmortem (Wheeler et al., 2005).

Statistical Analysis

Data from the GPE7 population were analyzed using the mixed model procedure (SAS Inst. Inc., Cary, NC), with carcass traits as dependent variables. The model included the fixed effects of sire line for GPE7 (Hereford, Angus, Red Angus, Simmental, Gelbvieh, Limousin, and Charolais), GPE7 dam line (Hereford, Angus, and MARC III), the interaction between sire line and dam line, year of birth (1999 and 2000), slaughter group (1, 2, 3, or 4) within year, and incidence of BRD or overall IPD as fixed effects. Incidence of BRD was used as a dependent variable in the analysis. Because of the low frequency of animals diagnosed and treated for pinkeye and footrot, these were used as dependent variables when incorporated into the IPD trait. Weaning age was included as a linear covariate. Sire was included in the model as a random effect nested within sire line.

The GPE8 population was analyzed using the same mixed model procedure of SAS, with the same carcass traits as dependent variables that were used for the GPE7 population. Briefly, the model included fixed effects for GPE8 sire line (Beefmaster, Brangus, Bonsmara, and Romosinuano and British breeds), GPE8 dam line (Angus and MARC III), year of birth (2001, 2002), slaughter group (1, 2, 3, or 4) within year, and BRD or IPD. Weaning age was included as a linear covariate. Sire was included in the model as a random effect nested within sire line. Statistical analyses for both populations were conducted using similar methods reported previously by White et al. (2005) and Casas and Stone (2006). Probability values were nominal and do not correct for multiple testing.

RESULTS

Table 1 shows the total number of animals, healthy animals, and animals diagnosed with BRD; total number of animals diagnosed and treated for any of the 3 pathogenic diseases; and total number of animals in each population. Levels of significance and traits significantly affected by the incidence of BRD and by IPD in the GPE7 and GPE8 populations are shown in Tables 2 and 3, respectively. The incidence of BRD and IPD were associated with differences in fat thickness and yield grade. Although similar effects were observed in both populations, separate traits were observed to be affected by BRD or IPD in the individual populations (Tables 2 and 3).

The incidence of BRD and IPD affected ($P < 0.05$) adjusted fat thickness and yield grade in the GPE7 and GPE8 populations (Table 2 and 3). Adjusted fat thickness from animals treated for BRD or IPD was significantly less than for unaffected animals. Similarly, animals diagnosed and treated for BRD or IPD in both the GPE7 and GPE8 populations had decreased yield grades when compared with animals that remained unaffected by disease during the production process (Table 2 and 3).

Table 1. Number of healthy animals treated for bovine respiratory disease (BRD) and incidence of pathogenic diseases (IPD)[1] in the GPE7[2] and GPE8[3] populations

Item	GPE7	GPE8
Healthy	442	441
BRD treated	126	149
IPD	200	180
Total	642	621

[1]IPD is the total number of animals diagnosed and treated for BRD, infectious bovine keratoconjunctivitis (pinkeye), and infectious pododermatitis (footrot).

[2]GPE7 = Cycle 7 of the Germplasm Evaluation project, includes steers with Hereford, Angus, Red Angus, Simmental, Gelbvieh, Limousin, and Charolais inheritance.

[3]GPE8 = Cycle 8 of the Germplasm Evaluation project, includes steers with Beefmaster, Brangus, Bonsmara, Romosinuano, Hereford, and Angus inheritance.

Although similar effects were observed for yield grade and carcass fat thickness across both populations, unique traits within populations were also affected. In the GPE7 population, animals treated for BRD or IPD had decreased ($P = 0.007$) estimated KPH measurements compared with untreated animals (Table 2 and 3). The incidence of BRD in the GPE8 population was associated with differences in shear force measurements; animals not treated for BRD had greater ($P = 0.05$) shear force values (Table 2). Furthermore, animals in the GPE8 population that were treated for IPD had greater retail product yield measurements and bone yield and had lesser ($P < 0.05$) HCW, fat yield, and adjusted fat thickness measurements compared with animals that did not require treatment for any disease (Table 3).

DISCUSSION

Animals are the most susceptible to BRD during times of stress, which leads to a subsequent depression of the immune system. These stressor events include weaning, transport, restraint, and commingling in confined areas. Other known factors affecting the probability include the previous plane of nutrition, genetics, and health history (Duff and Galyean, 2007). Becoming susceptible to BRD during these events leads to decreased feed intake (Sowell et al., 1999), potentially decreasing overall performance during the production process. Although the incidence of BRD in the current study varied, the factors mentioned may have played a role in the incidence of BRD.

Approximately 20% of the GPE7 population and 24% of the GPE8 population were affected by BRD,

Table 2. Effect of bovine respiratory disease in the GPE7[1] and GPE8[2] populations on means (±SE) for carcass composition and meat quality traits

	GPE7			GPE8		
Trait	Untreated	Treated	*P*-value	Untreated	Treated	*P*-value
LM area, cm^2	3.16 ± 0.07	13.09 ± 0.12	0.54	12.72 ± 0.07	12.78 ± 0.10	0.58
HCW, kg	371.20 ± 1.48	366.08 ± 2.60	0.06	341.25 ± 1.46	337.32 ± 2.38	0.12
Marbling[3]	538.58 ± 3.59	534.83 ± 6.28	0.56	497.16 ± 4.03	489.59 ± 6.07	0.22
Adjusted fat, cm	0.46 ± 0.01	0.40 ± 0.02	0.0007	0.41 ± 0.01	0.37 ± 0.02	0.01
KPH, %	2.34 ± 0.03	2.19 ± 0.05	0.007	2.15 ± 0.03	2.18 ± 0.06	0.68
Yield grade[4]	3.00 ± 0.04	2.81 ± 0.07	0.003	2.73 ± 0.04	2.59 ± 0.06	0.02
Choice, %	0.71 ± 0.02	0.64 ± 0.04	0.08	0.43 ± 0.003	0.38 ± 0.04	0.25
Dressing %	61.09 ± 0.07	60.89 ± 0.13	0.14	61.17 ± 0.09	61.05 ± 0.13	0.36
Retail product yield, %	61.75 ± 0.17	61.96 ± 0.30	0.50	62.42 ± 0.18	62.91 ± 0.27	0.07
Fat yield, %	25.03 ± 0.20	24.59 ± 0.36	0.24	24.26 ± 0.23	23.78 ± 0.34	0.15
Bone yield, %	14.12 ± 0.05	14.28 ± 0.10	0.10	14.43 ± 0.05	14.52 ± 0.08	0.25
Shear force, kg	4.26 ± 0.04	4.30 ± 0.08	0.64	3.77 ± 0.04	3.90 ± 0.06	0.05

[1]GPE7 = Cycle 7 of the Germplasm Evaluation project, includes steers with Hereford, Angus, Red Angus, Simmental, Gelbvieh, Limousin, and Charolais inheritance.

[2]GPE8 = Cycle 8 of the Germplasm Evaluation project, includes steers with Beefmaster, Brangus, Bonsmara, Romosinuano, Hereford, and Angus inheritance.

[3]Marbling: 400 = $slight^{00}$, 500 = $small^{00}$.

[4]Yield grades: USDA yield grade (USDA, 1997), 1.0 = leanest, 5.9 = fattest.

and BRD was the most common source of illness in these populations. The average of incidence of treated BRD is in agreement with the upper levels indicated by Snowder et al. (2007), who reported an average annual incidence of 17% BRD-affected animals from 1987 to 1992. Although the averages for the current population are within the upper levels and are greater than in previously reported studies (Schneider et al., 2009), they do not reach the epidemic levels reported by Snowder et al. (2007) of 33% in 1991 and 44% in 1990, which were attributed to management, year, and type of vaccine used.

The observation of decreased yield grade and adjusted fat thickness measurements in the current study confirms previous studies reporting similar results as a result of BRD incidence (Gardner et al., 1999; Montgomery et al., 2008). Gardner et al. (1999) found that Charolais steers affected with BRD at least once during the growing and finishing period were leaner than unaffected steers. Montgomery et al. (2008), using commercial heifers obtained from commercial sale barns, found that animals requiring at least 1 treatment for BRD were leaner than unaffected heifers. Furthermore, fat thickness measurements declined with each subsequent treatment (Montgomery et al., 2008). Although the number of treatments was not recorded in the present study, a decrease in fat thickness as a result of BRD incidence was similar in both independent populations

Table 3. Effects of overall incidence of pathogenic disease in the GPE7[1] and GPE8[2] populations for means (±SE) of carcass composition and meat quality traits

	GPE7			GPE8		
Trait	Untreated	Treated	*P*-value	Untreated	Treated	*P*-value
LM area, cm^2	13.14 ± 0.07	13.17 ± 0.10	0.75	12.74 ± 0.07	12.73 ± 0.09	0.93
HCW, kg	371.27 ± 1.55	367.87 ± 2.15	0.14	341.77 ± 1.49	336.51 ± 2.21	0.03
Marbling[3]	539.05 ± 3.75	535.11 ± 5.19	0.48	497.21 ± 4.08	490.62 ± 5.69	0.26
Adjusted fat, cm	0.46 ± 0.01	0.41 ± 0.01	0.0003	0.41 ± 0.01	0.36 ± 0.01	0.002
KPH, %	2.35 ± 0.03	2.23 ± 0.04	0.02	2.17 ± 0.04	2.13 ± 0.05	0.46
Yield grade[4]	3.02 ± 0.04	2.83 ± 0.05	0.0006	2.74 ± 0.04	2.58 ± 0.06	0.004
Choice, %	0.72 ± 0.02	0.66 ± 0.03	0.14	0.43 ± 0.03	0.39 ± 0.04	0.39
Dressing %	61.11 ± 0.08	60.90 ± 0.11	0.06	61.16 ± 0.09	61.10 ± 0.12	0.65
Retail product yield, %	61.70 ± 0.17	62.00 ± 0.25	0.27	62.36 ± 0.18	63.00 ± 0.25	0.01
Fat yield, %	25.05 ± 0.21	24.71 ± 0.30	0.28	24.36 ± 0.23	23.59 ± 0.31	0.01
Bone yield, %	14.12 ± 0.06	14.20 ± 0.08	0.33	14.41 ± 0.06	14.57 ± 0.08	0.03
Shear force, %	4.26 ± 0.04	4.28 ± 0.07	0.79	3.78 ± 0.04	3.87 ± 0.06	0.15

[1]GPE7 = Cycle 7 of the Germplasm Evaluation project, includes steers with Hereford, Angus, Red Angus, Simmental, Gelbvieh, Limousin, and Charolais inheritance.

[2]GPE8 = Cycle 8 of the Germplasm Evaluation project, includes steers with Beefmaster, Brangus, Bonsmara, Romosinuano, Hereford, and Angus inheritance.

[3]Marbling: 400 = $slight^{00}$, 500 = $small^{00}$.

[4]Yield grades: USDA yield grade (USDA, 1997), 1.0 = leanest, 5.9 = fattest.

of varying genetic backgrounds, confirming the association of incidence of BRD with less desirable carcass performance in beef cattle. However, it is important to note that the identification of an effect on both yield grade and adjusted fat thickness was not surprising because adjusted fat thickness is a major component in the calculation of yield grade.

Animals affected with BRD have been reported to have smaller marbling scores and lighter HCW when compared with unaffected cattle (Montgomery et al., 1984; Gardner et al., 1999; Roeber et al., 2001; Montgomery et al., 2009; Schneider et al., 2009). No such associations were detected between BRD-affected and unaffected animals when evaluating marbling score or HCW. However, an association was observed in the GPE8 population, in which animals affected by IPD were shown to have lighter HCW than unaffected animals. A plausible explanation for the lack of association between incidence of BRD and carcass traits, other than fat thickness, yield grade in both populations, KPH in the GPE7 population, and shear force in the GPE8 populations, could be the production system used at the US Meat Animal Research Center. Animals are monitored extensively by a staff veterinarian and beef cattle technicians. The early detection and effective treatment of affected animals may explain why BRD did not significantly affect the majority of carcass traits previously reported as influenced by BRD.

Another plausible explanation for why similar traits were not reported in the current study was the difference in production systems used in previous studies. Animals in previous studies (Montgomery et al., 1984; Gardner et al., 1999; Roeber et al., 2001; Montgomery et al., 2008; Schneider et al., 2009) were raised under varying or unknown management systems, for which production practices before the finishing process were unknown. However, this variation in background allowed for the use of a larger population of cattle, which in turn may have allowed for the detection of effects in other variables not detected in the current study. Both populations (GPE7 and GPE8) were developed under similar management systems and were raised in the same environment. The decision to use the GPE7 and GPE8 populations because of their similar production backgrounds did not allow for the inclusion of animals from other production systems, thereby decreasing the overall population size when compared with other studies. This is a plausible explanation for why differences in carcass traits that were observed to be influenced by BRD in previous studies were not detected here.

When evaluating the incidence of BRD and IPD in the GPE7 and GPE8 populations, a difference in frequency was noted between the 2 traits. Approximately 83% of all diagnosed and treated animals in the GPE8 population were diagnosed with BRD, as opposed to 63% of the GPE7 population. The difference observed in these 2 populations may be due to differences in the genetic backgrounds of GPE7 and GPE8 steers. Breeds that constitute the GPE7 population have been described (Snowder et al., 2005) as being more susceptible to disease. Previous studies (Frisch, 1975, 1976) have also reported that animals of *B. indicus* descent are more resistant to pinkeye and footrot, specifically when compared with animals of *B. taurus* descent. The possible resistance of the GPE8 population to 2 of the pathogenic diseases (pinkeye and footrot) included in the overall pathogenic disease trait possibly explains the observed difference between these 2 populations for the overall IPD trait. However, animals in the GPE8 population affected with IPD responded differently when IPD was found to be associated with carcass traits. Animals treated for IPD had lighter HCW and reduced fat yield measurements but increased retail product yield and bone yield measurements. Thus, animals treated for IPD in the GPE8 population had smaller and leaner carcasses than animals that remained unaffected by pathogenic disease.

The effect on adjusted fat thickness and yield grade attributed to IPD may in fact have been strongly influenced by the proportion of incidence attributable to BRD cases included in IPD. When evaluating yield grade and fat thickness in animals diagnosed with BRD, animals from the GPE7 and GPE8 populations had almost identical means for these traits as a result of BRD or IPD. Similarly, the differences observed between BRD-affected animals diagnosed with IPD and healthy animals also were almost identical for yield grade and fat thickness. Thus, the significant results observed for overall IPD were in all likelihood driven by the proportion of treated BRD cases in both populations.

Results suggest that evaluation of health status, specifically, contracting disease and the subsequent effects on production traits, is necessary to select animals effectively for a variety of desirable traits. Currently, research is being conducted to identify genetic markers that may help identify animals predisposed to resistance to certain diseases. Although QTL regions across the genome have been identified as areas that may harbor markers of value toward selection of disease-resistant animals (Casas and Stone, 2006; Casas et al., 2007; Casas and Snowder, 2008), it is also important to note that these regions may in fact overlap with regions that have been described to harbor markers of value when selecting animals for increased carcass quality and value (Casas et al., 2000, 2003, 2004; MacNeil and Grosz, 2002; Abe et al., 2008). Thus, overselection for 1 trait may adversely affect another desirable trait.

Although significant effects were observed for carcass composition and quality traits in association with BRD and IPD, the numerical differences were minimal. However, if these effects were observed consistently in the beef industry, the economic impact of BRD and IPD on carcass composition and quality traits would cease to be economically negligible. Thus, these results validate and further strengthen previous reports of a negative relationship between BRD and carcass composition and yield traits.

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