HEALTH OF GROWING AND FINISHING STEERS:

EFFECTS ON PERFORMANCE, CARCASS

TRAITS AND MEAT TENDERNESS

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NOMENCLATURE

AOAC	Association of Official Analytical Chemists
ADG	Average Daily Gain
AVBP	Anterioventral Bronchopneumonia
BRD	Bovine Respiratory Disease Complex
^{o}C	degrees Celsius
cm	centimeters
d	days
g	grams
HCW	Hot Carcass Weight
hr	hours
IMPS	Institutional Meat Purchase Specifications
kg	kilograms
mg	milligrams
USDA	United States Department of Agriculture
WBS	Warner-Bratzler Shear
YG	USDA Final Yield Grade

CHAPTER I

INTRODUCTION

Economically, the most important disease affecting feedlot cattle throughout North America is the bovine respiratory disease complex (Church and Radostits, 1981; Yates, 1982; Martin et al., 1989; Wittum et al., 1993; Edwards, 1996). Commonly referred to as BRD, this disease complex is responsible for 75% of the morbidity and over 50% of feedlot mortality (Edwards, 1996). Complications with the respiratory system are most prevalent among newly arrived feeder cattle (Townsend et al., 1989; Edwards, 1996) and account for over 90% of all clinical treatments during the first four to five weeks at the feedyard (Edwards, 1988; Martin et al., 1989). Respiratory problems continue throughout the finishing phase; Edwards (1988) reported that respiratory disease accounted for 65% of the morbidity and mortality cases among 372,175 cattle observed in eleven Kansas feedlots, while Martin et al. (1982) reported respiratory disorders occurred among 64, 65 and 72 percent of feedlot calves in three different years. Of the respiratory problems associated with feedlot cattle, bronchopneumonia and fibrinous pneumonia have been reported to be the most common (Edwards, 1988 and Martin et al., 1982, respectively).

Although the costs attributable to the treatment of BRD are substantial (Martin et al., 1982; Perino, 1992), the economic impact of BRD may be even greater. Additional production losses have been associated with BRD including reductions in live and carcass weights as well as feed efficiencies. Results from the Texas A&M Ranch-to-Rail program (McNeill et al., 1996) revealed steers diagnosed as "healthy" during the finishing phase generated more profit per head, had higher average daily gains (2.93 vs. 2.78 pounds/day) and had 12% more U.S. Choice carcasses than cattle identified as "sick". Martin et al. (1989), Bateman et al. (1990) and Morck et al. (1993) reported rate of gain was reduced among feedlot cattle treated for respiratory disease. However, several other studies that utilized clinical health evaluations determined that morbidity did not impact average daily gain during the finishing phase of production (Cole et al., 1979; Townsend et al., 1989; Jim et al., 1993; Griffin and Perino, 1992).

Discrepancies about the association of clinical evaluations and feedlot performance exist; these may be due to imprecision in the antemortem detection of BRD in cattle. Wittum et al. (1996) reported 35% of steers were treated for respiratory disease between birth and slaughter; in contrast, pulmonary lesions were evident in 72% of all lungs evaluated at slaughter (78% of treated steers and 68% of untreated steers). In their study, only 27% of the steers were treated for respiratory disease and had lung lesions evident at slaughter; thus, a majority of the "healthy" steers had pulmonary lesions at slaughter. Wittum et al. (1996) concluded clinically diagnosed respiratory disease was not associated with ADG, but respiratory lesions present on the lungs at slaughter were associated with feedlot ADG. Calves with pulmonary lesions at slaughter averaged 0.076 (Wittum, et al., 1996) and 0.034 (Bryant, 1997) kg lower daily weight gains during the finishing period even though ADG of steers treated for clinical disease was not different from ADG of nontreated steers. Additional research by Bryant et al. (1996) revealed calves with lung lesions had 0.12 kg less daily weight gain; this resulted in lighter carcass weights (323 versus 356 kg, respectively). Hence, the lack of difference in ADG reported by (Cole et al., 1979; Townsend et al., 1989; Jim et al., 1993; Griffin and Perino, 1992) may have been masked by the presence of lung lesions in non-medicated cattle.

Even though clinical health evaluations are imprecise in detecting illness and the effect of health on performance, evaluating bovine lungs for lesions associated with BRD indicates respiratory disease has detrimental effects on cattle performance and perhaps on carcass characteristics. Research documenting carcass and meat quality differences between "healthy" and "sick" cattle (as determined via clinical or postmortem evaluations) during the finishing phase of production is limited.

For the current study, clinical evaluations (records of morbidity treatments during the finishing phase), lung lesions associated with bronchopneumonia (Bryant, 1997) and a classification of lung lymph gland activity (temporal classification system) were used to determine the effects of calf health on daily gain, carcass traits and meat tenderness.

CHAPTER II

REVIEW OF LITERATURE

Lung Lesions Associated With Bronchopneumonia

Lungs infected with bronchopneumonia are inflamed as a result of causal organisms/agents that gain entry into the respiratory tract through the air (Thomson, 1988). Bronchopneumonia develops at the bronchiolar-alveolar junctions (Thomson, 1988) and spreads lobularly into the lung parenchyma (Thomson, 1981); the ventral portions of anterior lobes are affected most commonly (Thomson, 1988). As a result of inflammation, air passages and tissues are flooded with an exudate which results in irregularly consolidated areas of the lung that appear dark red though greyish pink to grey (Bryant, 1997). The color and pliability of the lung varies with lesion age and the processes involved; older lesions are gray and firm (Thomson, 1988). When lungs become severely infected, exudate and cellular debris extends through the alveoli and surrounding interstitium (Bryant, 1997) resulting in lung congestion with red to gray hepatization and resolution (Bryant, 1997). A lung scoring system developed by Bryant (1997) indicated that lesions occurring in the cranial ventral lung fields can be used as an objective measure of past respiratory disease.

Feedlot Performance

Implant Protocol. The economics of beef cattle production depend heavily on performance of animals during the finishing period. Greater daily gains reduce the time needed to achieve a weight acceptable by the market. This increases the potential for positive economic returns. Exogenous hormonal implants are used widely in the beef industry to increase rate of weight gain. In an expansive review of implant effects on performance, carcass traits and meat tenderness of feedlot steers, Duckett et al. (1997a) summarized that ADG was increased 18%. However, the specific implant protocol is of great importance; single combination implants containing a strong estrogen and androgen resulted in the highest daily gains, whereas single androgen implants alone did not increase ADG (Duckett et al., 1997b). Interestingly, implant regimes that utilized repeated implants of the same composition further enhanced daily gains assessed on a live or a carcass weight basis. Repeated implants of strong estrogen and androgen proved to be the most beneficial from a weight gain aspect, followed closely by repeated strong estrogen implants; but, repeated implants of androgen and mild estrogen did not enhance daily gain above that of non-implanted feedlot steers (Duckett et al., 1997b).

Age-Class and Pre-Feedlot Management. Totusek (1971) observed as initial age (and accordingly, weight) of feedlot cattle increased, feed intake, rate of gain and feed required per pound of gain increased; additionally, fewer days-on-feed were required for older cattle to reach a specified grade endpoint. Lunt and Orme (1987) provided additional support that age-class or, more specifically, weight at feedlot entry influences daily gains; yearlings utilized by Lunt and Orme had higher feedlot gains than calf-fed siblings. Ferrell et al. (1978) concluded rate of gain favored large-type steers even though feed efficiency was similar for large and medium types.

Many producers implement backgrounding systems to utilize available forages and to allow cattle to grow and mature prior to feedlot entry. Dinius and Cross (1978), Dikeman et al. (1985) and King (1993) reported the management regimen utilized prior to feedlot placement contributes to feedlot performance. Dinius and Cross (1978) observed that cattle gained carcass weight rapidly when shifted from a forage to a concentrate diet. Bowling et al. (1978) noted steers grown either on grass for 18 weeks or supplemented with grain for 60 days while grazing grass for 18 weeks were approximately six months older when they reached weights and grades comparable to steers fed in a drylot. King (1993) reported steers weaned and placed in the feedlot at 3.5 months of age had lower daily gains than calves placed at 7.9 months of age, similar to the findings of Dikeman et al. (1985). However, feed:gain ratios favored calves weaned and placed directly in the feedyard as compared to steers backgrounded on wheat pasture or grazed on native range prior to feedlot placement (Dikeman et al., 1985; King, 1993). Ridenhour et al. (1982) reported crossbred steers continuously fed a high concentrate ration achieved higher daily gains than steers backgrounded on either 50% concentrate or on irrigated wheat pasture prior to receiving their 85% finishing ration. Although feed:gain ratios were not different for steers placed in the feedyard as calves versus those grown on wheat pasture or a 50% concentrate ration to a mean weight of 273 kg, all of these groups had more desirable feed conversions than steers placed on the high concentrate ration at 364 kg live weight.

Dietary Energy. Dietary energy is the primary factor responsible for the feeding value of grains (Houseknecht et al., 1988). Processing of grain for use in finishing rations (whole, cracked, flaked) as well as the type of grain used will have a substantial effect on feeding value (NRC, 1984; NRC, 1996). Processing grain using a wet method, such as steam flaking, can improve feeding value by 12 to 20% above dry rolling (Hale, 1984; Brandt et al., 1988). Although whole or cracked yellow dent corn has a higher feeding value than milo (NRC, 1984; NRC, 1996), the difference between these two grains in feeding value is non-existent when wet processed (Brandt et al., 1992).

Health. Martin et al. (1989) and Morck et al. (1993) reported rate of gain was reduced among feedlot cattle treated for respiratory disease. Wittum and Perino (1995) documented calves treated for clinical BRD had 0.04 kg lower ADG than calves never exhibiting clinical disease during the finishing period.

McNeill et al. (1996) concluded steers never diagnosed as "sick" during the finishing phase had higher daily gains (1.33 versus 1.26 kg/day) and required less feed per pound of gain than "sick" steers. In contrast, Townsend et al. (1989) reported the occurrence of respiratory disease among bulls placed on test did not affect overall daily gains; however, all of these bulls had received an intranasal, modified live virus vaccination for IBR and PI_3 upon arrival at the test station. Vaccination against pneumonia (IBR, PI_3, RSV) results in fewer pulmonary lesions and lower mortality rates among lambs (Hansen and McCoy, 1995). Cole et al. (1979), Jim et al. (1993) and Griffin et al. (1995) also detected no significant differences between "sick" and "healthy" cattle in ADG and feed:gain, although numerical trends indicated cattle not treated for BRD had a higher ADG than cattle treated for BRD.

van der Mei and van den Ingh (1987) and Wittum et al. (1996) concluded clinical or subclinical BRD results in permanent lesions on bovine lungs even after cattle recover from clinical or subclinical respiratory disease. Wittum et al. (1996) reported 35% of steers were treated for respiratory disease between birth and slaughter; in contrast, pulmonary lesions were evident in 72% of all lungs evaluated at slaughter (78% of treated steers and 68% of untreated steers). Bryant (1997) reached a conclusion similar to that of Wittum et al. (1996); 43% of all calves had lung lesions at slaughter. A slightly higher incidence of lung lesions was found among cattle diagnosed with respiratory disease as compared to those never diagnosed (59 vs 42%). Even though ADG of steers treated for clinical disease did not differ from that of non-treated steers (Wittum et al., 1996), respiratory lesions on the lungs at slaughter were clearly associated with feedlot ADG (Wittum et al., 1996; Bryant, 1997). Other research has documented that weight gain of animals with significant lung lesions was depressed by approximately three percent among veal calves (Pritchard et al., 1981) and over seven percent among beef animals (Thomas et al., 1978). Wittum et al. (1996) concluded calves with pulmonary lesions at slaughter had 0.076 kg slower ADG during the finishing period and Bryant et al. (1996) reported that daily weight gain among calves with lung lesions was reduced by 0.02 to 0.40 kg. When linear regression was used to estimate the effects of lung lesions evident at slaughter on feedlot ADG, Bryant (1997) reported cattle with lung lesions gained .034 kg less per day than cattle without lesions at slaughter in MARC III calves. Interestingly, daily gains of MARC III cattle with bronchopneumonia type lung lesions at slaughter were affected even more; daily gains were reduced by .046 kg per day for cattle with the bronchopneumonia type lesions while lesions of other types were not significant. Thomas et al. (1978) reported beef cattle diagnosed with enzootic pneumonia or pneumonic consolidation weighed less than non-affected cattle throughout the growth period; this reduced daily gains and required that "sick" cattle be fed additional days to achieve similar slaughter weights. Tadic and Pogacnik (1988) concluded enzootic bronchopneumonia of cattle is a serious medical and economic problem in Yugoslavia causing a loss of five kilograms of beef per animal fattened.

Carcass Traits

Time-on-Feed. Although numerous factors can influence the percentage of cattle grading U.S. Choice, the most common method to enhance grade is extending the time that animals are fed a high concentrate diet. As time-on-feed is extended, marbling score and quality grade increase (Zinn et al., 1970; Campion and Crouse, 1975; Harrison et al., 1978; Schroeder et al, 1980; Tatum et al., 1980; Dolezal et al., 1982; May et al., 1992; Van Koevering et al., 1995). With calf-feds, Zinn et al. (1970) noted that marbling score and carcass grade increased significantly up to 240 days on feed. Williams et al. (1989) and May et al. (1992) also found that added time-on-feed improved the quality determinants of muscle; carcasses from cattle fed 112 days had significantly higher marbling scores than did carcasses from cattle fed 84 days. Yet beyond 112 days-on-feed, marbling score remained constant (Williams et al., 1989; May et al., 1992). Upon examining diet energy density and time-on-feed, Burson et al., (1980) noticed that, in general, group means for USDA quality grade factors increased as diet energy density and time-on-feed increased.

When cattle are fed for an extended time period to increase the percentage of U.S. Choice and higher carcasses, increased carcass fatness may result; an increase in time-on-feed is associated with increased deposition of subcutaneous, internal, intermuscular and intramuscular fat (May et al., 1992). Williams et al. (1989) observed that as time-on-feed increased from 84 to 112 days, mean values for fat thickness and estimated percentage of kidney, pelvic and heart fat, as well as the percentage of fat removed from the carcasses during hot fat trimming, increased. Burson et al. (1980) observed means for adjusted fat thickness and percentage kidney, pelvic and heart fat were lowest for carcasses from cattle fed sub-maintenance diets; steers fed an energy dense ration for 175 days had the most fat both externally as well as internally. In a similar study conducted by Ferrell et al. (1978), most of the increase in carcass weight due to increased energy density of the diet was a result of an increase in fat deposition. Houseknecht et al. (1988) reported that source of dietary energy did not alter quality grade, but the quantity of energy provided by the diet did affect quality grade; compared to low energy diets, cattle fed high energy diets yielded carcasses higher in quality grade. Additionally, heifers fed high energy diets had higher dressing percentages, greater subcutaneous fat thicknesses, larger *longissimus* areas, higher percentages of internal fat and higher numerical yield grades than heifers fed a low energy diet (Houseknecht et al., 1988)

Increasing carcass fatness by extending time-on-feed results in higher numerical yield grades (Dinius and Cross, 1978; Burson et al., 1980; Tatum et al., 1980; Dolezal et al., 1982; Williams et al., 1989; May et al., 1992), but may have positive effects on dressing percentage (Dinius and Cross, 1978; May et al., 1992; Van Koevering et al., 1995). Ribeye area may increase with additional days-on-feed (Schroeder et al., 1980; Williams et al., 1989; May et al., 1992; Van Koevering et al., 1995). Schroeder et al. (1980) compared differences between forage- and grain-finished beef and observed that additional time-on-feed markedly increased ribeye area. Williams et al. (1989) noticed similar results;

mean values for ribeye area increased with extended time-on-feed from 84 to 112 days. These increases in ribeye size may reflect increases in live and carcass weights or size but not increased muscularity because ribeye area per unit weight was not increased (Schroeder et al., 1980; Williams et al., 1989).

Implant Protocol. Extensive research has shown that implant type, dosage level and time of administration can substantially impact carcass grade traits. An expansive review of implant effects on performance, carcass traits and meat tenderness of feedlot steers was summarized by Duckett et al. (1997a). This review, which incorporated information from 37 trials with steers, concluded dressing percentage, fat thickness, percentage kidney, pelvic and heart fat, adjusted ribeye area, yield grade, marbling score, incidence of dark cutters and the percentage of carcasses grading U.S. Choice did not differ between implanted and non-implanted controls. However, implanted steers yielded 5% heavier carcasses and had ribeye areas 3% greater than non-implanted controls.

Contradicting the summarization by Duckett et al. (1997a), Mathison and Stobbs (1983) and Bartle et al. (1992) reported estrogenic implants of Synovex-S® or Compudose® increased dressing percentage. Huffman et al. (1991) found implanting with Finaplix-S® alone reduced dressing percentage but not when used in combination with estrogens. Likewise, in 11 comparisons of 108 individual trials, Duckett et al. (1997a) detected an increased fat thickness for implanted steers of British breeding and in eight trials (Duckett et al., 1997a) yield grade was altered by implanting. As mentioned previously, marbling score did not differ between implanted and control steers in the summary by Duckett et al. (1997a), but overall, implants decreased marbling score by a mean of 24 points from the small^{40} average reported for non-implanted animals. Consequently, the percentage of U.S. Choice carcasses for implanted steers was decreased by 14.5% (from 74% reported for controls). Johnson et al. (1995) reported similar results; implanted steers had lower marbling scores than controls but multiple implants of Synovex-Plus® had a more pronounced impact on marbling score than a single implant of Synovex-Plus®.

Johnson et al. (1995) and Al-Maamari et al. (1995) reported that when steers were fed to a time-constant endpoint (148 days), implanted steers were heavier both live and on a carcasses weight basis, in addition to having more advanced skeletal and overall maturities, larger ribeye areas and more masculine carcasses than the non-implanted steers. Also, implanted steers had lower marbling scores, which resulted in lower percentages of U.S. Choice and higher percentages of U.S. Select carcasses. A second implant of Synovex-Plus® produced heavier slaughter and carcass weights as well as more masculine carcasses that tended to have the least marbling compared to those that received a single implant at the onset of the finishing phase.

Age-Class. Feeder cattle maturity and age can also influence performance and carcass merit. Calves (approximately 9 months of age), yearling (approximately 12 months of age) and long-yearling (approximately 18 months of age) feeder cattle require different management programs to meet slaughter endpoints. The time-on-feed required to attain a given weight and level of fatness varies considerably with age. Many advancements have been made in beef cattle genetics with respect to growth and performance traits; with the increase in growth rate, many producers are sending their calves to the feedlot directly after weaning.

Diversification of the United States cattle population during the past two decades has resulted in many different cattle types, leading to increased variability and inconsistency during the growing and finishing phases of production. As a result, many different management and marketing strategies have been developed to achieve maximum profitability for different cattle types. Lunt and Orme (1987) studied the differences between weanling- and yearling-fed heifers slaughtered when live weight approached 443 kilograms. In the 1987 study, weanlings were fatter, had more kidney, pelvic and heart fat, merited higher (less desirable) USDA yield grades, had more desirable USDA quality grades and had higher dressing percentages; ribeye area was not different between the two age-classes.

Burton et al. (1993) and Deering et al. (1993), in related studies, determined the effects of feedlot age (maturity) at slaughter on carcass traits and meat tenderness as well as boxed beef yield. All carcass traits were adjusted to the mean fat thickness of 1.40 cm. Deering et al. (1993) reported early and normal weaned steers sent directly to the feedyard yielded lighter carcasses than backgrounded steers; no differences were noted among age treatments for marbling score, ribeye area, percentage kidney, pelvic and heart fat or yield grade. Burton et al. (1993) noted skeletal maturity scores were not different for steers placed directly in the feedlot versus backgrounded steers. However, dry wintering and season-long grazing resulted in carcasses with more advanced skeletal maturities. Dikeman et al. (1985) examined differences between accelerated (85% concentrate for 140 days) and conventional (backgrounded on prairie hay and sorghum grain for 140 days and then finished on 82% concentrate for 116 days) feeding systems using Angus x Hereford cattle. Cattle on the accelerated system were lighter muscled and had less fat, lower numerical USDA yield grades, lower marbling scores and lower USDA quality grades than cattle on the conventional system. However, cattle in this study were not slaughtered at a constant weight. Cattle on the accelerated system may have been fatter than those on the conventional system had the accelerated cattle been slaughtered at comparable weights. Garcia-De-Siles et al. (1982) concluded at a constant weight endpoint, marbling score increased significantly with animal age; fat thickness was greater for steers older than 451 days when compared with steers less than 425 days at slaughter.

Genetics. Beef cattle improvement programs traditionally have focused on the alteration of genetic factors associated with live animal growth traits. However, the cattle industry is increasingly under pressure to produce lean beef while maintaining a tender, palatable product. As the beef industry becomes more value-based driven, emphasis on body composition traits will be of greater importance in the design of breeding programs. Considerable variation exists in the composition of beef carcasses, a sizable portion of which has a genetic origin (Cundiff and Gregory, 1995).

Fed to an age- or time-in-feedlot-constant basis, British type steers produced carcasses with more external fat and higher marbling scores than Continental type steers and yielded slightly lighter, fatter carcasses with smaller ribeye areas (Morris et al., 1990; Cundiff et al., 1993; Cundiff et al., 1994; Marshall, 1994; Wheeler et al., 1996). Wheeler et al. (1996) noted, regardless of endpoint, British type steers had the smallest *longissimus* areas. Additionally, at a constant carcass weight, Hereford X Angus carcasses had less subcutaneous and intramuscular fat than Continental type steers (Wheeler et al., 1996). When adjusted to a constant fat thickness, sire breed significantly affected marbling score (Wheeler et al. 1996). Differences in *longissimus* area were non-existent with the exception that Jersey sired carcasses had the smallest *longissimus* areas (Morris et al., 1990). Sherbeck et al. (1995) reported that at a constant slaughter weight, carcasses of steers with Brahman influence (at least 25% Brahman) had larger *longissimus* muscle areas, more advanced physiological maturity indices and lower marbling scores than straightbred Hereford steers. Additional studies have indicated that *Bos taurus* influenced steers yield fatter (Crouse et al., 1989), higher quality carcasses (Koch et al. 1982; Crouse et al., 1987; Crouse et al., 1989) that have similar *longissimus* muscle areas to carcasses from *Bos indicus* influenced cattle (Koch et al. 1982; Crouse et al., 1987; Crouse et al., 1989).

Health. Research concerning the relationship between BRD and carcass characteristics is very limited. Jim et al. (1993) concluded that "sick" and "well" cattle did not differ in carcass weight, fat depth, marbling score or ribeye area; van der Mei and van den Ingh (1987) and Bryant et al. (1996) concluded lung lesions in calves at the time of slaughter were correlated with lighter hot carcass weights. McNeill et al. (1996) reported steers deemed as "sick" at some point during the finishing period graded 27% U.S. Choice compared to 39% for "non-sick" steers.

Tenderness

Historically, beef production economics have revolved around efficiently converting feed to live weight gain; value-based marketing has enhanced the importance of carcass grade traits. However, tenderness is one of the most important factors associated with consumer acceptance of beef products (Lorenzen et al., 1993; Smith et al., 1995). In fact, Savell et al. (1987, 1989) documented tenderness was the single most important determinant affecting taste or the perception of taste by consumers.

Physiological Age. When loins from beef carcasses representing "A", "B", "C" or "E" maturity (USDA, 1989) and marbling scores from Practically Devoid to

Moderately Abundant were evaluated, Smith et al. (1982) reported shear force values were altered; "A" maturity carcasses had the lowest and "E" maturity carcasses had the highest shear force values. Because the pre-slaughter nutritional history of the cattle utilized by Smith et al. (1982) was not known, Miller et al. (1983) evaluated carcasses from crossbred steers visually estimated to be 2 to 5 years of age and fed a high concentrate diet for 185 days. When *longissimus* shear force values from carcasses representing the "youthful" ("A" and "B") maturity classification were compared with "old" ("C" and "E") maturity carcasses similar in intramuscular and subcutaneous fat, Miller et al. (1983) concluded shear force did not differ due to physiological age. Similar results were reported by Hawrysh et al. (1975) when *longissimus* tenderness values from 3.5 year old cows fed a high concentrate ration were compared to values for grain-fed steers. Shackelford et al. (1995) also documented that Warner-Bratzler shear force values were not different for *longissimus* steaks from yearling vs. 2-year-old heifers (5.99 vs. 6.08 kilograms, respectively), even though 28% of the 2-year-old carcasses qualified for the "C" skeletal maturity group. Field (1996) reported that among loin steaks from "A" and "C" maturity heifers ("B" maturity carcasses were not included in tenderness evaluations), neither sensory panel nor Warner-Bratzler shear values differed. Additionally, and possibly of greater importance, Field (1996) reported that variability in panel tenderness or shear force between the "A" and "C" maturity groups was not different.

Genetics. Differences in palatability attributable to breed type have been studied extensively (Koch et al., 1976; Koch et al., 1979; Koch et al., 1982; Cundiff et al., 1990; Wheeler et al., 1996), but the demand for lean, tender beef (Smith et al., 1992, 1995) has created a renewed interest in identifying cattle genetically superior in tenderness traits. Traditionally, marbling score has been used to segment carcasses into groups of expected palatability (USDA, 1989a), but marbling score alone can not predict beef tenderness (Jeremiah, 1970; Campion and Crouse, 1975; Seideman et al., 1987; Wheeler et al., 1994).

As the proportion of *Bos indicus* inheritance increases, beef tenderness decreases (Koch et al., 1982; Crouse et al., 1987, 1989; Whipple et al., 1990; Sherbeck et al., 1995). Beef from *Bos indicus* cattle is more variable in tenderness than beef from other biological types (Koch et al., 1976; Koch et al., 1979; Koch et al., 1982; Cundiff et al., 1990). Additional research indicates that dairy (Koch et al., 1976; Armbruster et al., 1983; Knapp et al., 1989; Thonney et al., 1991) and double muscled breeds produce more tender meat than beef breeds (Tatum et al., 1990; Wheeler et al., 1996). Koch et al. (1979) reported meat from Angus-sired steers had lower WBS values than meat from Hereford, Red Poll, Brown Swiss, Gelbvieh, Maine Anjou or Chianina sires. In general, differences in tenderness between European breeds and British breeds (primarily Hereford, Angus and their crosses) are small (Koch et al., 1976; Koch et al., 1979; Koch et al., 1982; Cundiff et al., 1990; Wheeler et al., 1996). Nevertheless, considerable variation in beef tenderness exists within breeds (Suess et al., 1966).

Time-on-Feed. Time-on-feed is related to the tenderness of beef (Tatum et al., 1980; Burson et al., 1980; Dolezal et al., 1982; Aalhus et al., 1992; May et al., 1992; Van Koevering et al., 1995). For yearling cattle fed a conventional high-energy finishing diet, a feeding period of a specified length (84 days according to May et al., 1992) is sufficient to assure that beef is desirable in tenderness and overall palatability. However, McKeith et al. (1985a, b) reported that differences in shear force attributable to the length of time cattle were fed a high concentrate diet was dependent on cattle type; steaks from Angus steers did not respond to additional time-on-feed whereas shear force values for steaks from Brahman steers decreased between 112 and 168 days-on-feed.

Feeding Regimen. The cost of available feedstuffs combined with the variability and inconsistency of the United States cattle population has required producers to develop different management and marketing strategies in order to maximize profit for different cattle types. However, differences in management, as related to diet, have the potential to influence meat tenderness. Miller et al. (1987a) evaluated the effects of pre-slaughter feeding regimen on meat quality of steers slaughtered at a common age. For their study, steers were fed to achieve live weight gains of 0.41 (low) or 0.68 (high) kg per head from 8 to 14 months of age, after which steers were fed a high concentrate finishing ration. Shear force values did not differ for *longissimus* steaks from steers fed the high energy diet (4.10 kg) compared to those fed the low energy diet (4.61 kg). Additional work by Bowling et al. (1978), Burson et al, (1980), Bidner et al., (1985), Fishell et al. (1985), Miller et al. (1987b) and Berry et al. (1988) has documented that muscle fiber tenderness and overall tenderness values were not affected by pre-slaughter growth rate or nutritional regimen. However, Smith et al. (1977) reported as diet energy density increased, meat palatability was improved. Dikeman et al. (1985) also reported that, despite lower USDA quality grades, steers reared on an accelerated production system produced more palatable steaks than those reared conventionally.

Implant Protocol. Implant protocol can affect beef tenderness (Foutz et al., 1990; Apple et al., 1991; Gardner et al., 1996). When administered outside the window of acceptability, implants increase the percentage of "tough" steaks. Foutz et al. (1990) reported steaks from non-implanted steers were more tender than steaks from steers with Synovex-S®, Revalor-S® or Synovex-S® plus Finaplix-S® (TBA) implants; consequently, a higher percentage of steaks from non-implanted steers were classified as "tender". Gardner et al. (1996) and Schutte et al. (1996) reported implant protocol had no detrimental effect on mean tenderness values; however, Gardner et al. (1996), using top round steaks, noted that multiple implants of Revalor-S® (aggressive implanting) resulted in greater shear force variation than multiple implants of Implus-S® (normal implanting). The review of implant effects by Duckett et al. (1997a) reported WBS values were not significantly different for implanted versus non-implanted controls even though overall WBS was increased by 0.27 kg for implanted steers.

Quality Grade. The U.S. standards for grades of beef formulated in 1916 provide for uniform reporting of the dressed beef markets according to grades. These standards eventually were revised, promulgated by the Secretary of Agriculture in 1926 as the Official United States Standards for the Grades of Carcass Beef and supplied the basis for grading when the voluntary beef grading and stamping service was begun in May 1927. The standards for slaughter livestock were to be directly related to the grades of the carcasses they produce. Quality grades were intended to segment carcasses into groups based on the expected desirability (tenderness, juiciness, flavor) of product or on the relative "risk" of obtaining an undesirable (tough, dry, off-flavored) product and were based on physiological age (determined by chronological indicators) and marbling score. Once segmented into chronological age groups, marbling traditionally has been used as the primary determinant of palatability. However, controversy exists regarding the importance of marbling on tenderness.

Many researchers have reported that as degree of marbling increased, tenderness increased (Jennings et al., 1978; Tatum et al., 1980; Dolezal et al., 1982; May et al., 1992; Berry, 1993); others (Parrish et al, 1973; Parrish , 1974; Prost et al., 1975; Smith et al., 1984; Wheeler et al., 1994) have reported very low or non-existent associations between marbling and tenderness. Additional work indicates intramuscular fat in posture cuts (ribs and loins) is associated with eating quality (Tatum et al., 1982; Smith et al., 1984, 1987), but a comprehensive review of the literature (Jeremiah, 1970) revealed degree of marbling explained only 12 to 24% of the variation in beef palatability. Campion and Crouse (1975) as well as Wheeler et al. (1994) reported degree of marbling accounted for only 5% of the variation in WBS values, while Crouse and Smith (1978) indicated marbling accounted for only 6% of the variation in taste panel acceptability. Jones et al. (1991) reported degree of marbling had no effect on initial or overall tenderness when *longissimus thoracisis* steaks from 229 carcasses were evaluated; however, the percentage of unacceptable ratings for steaks, based on overall palatability, declined from 38.5% for steaks with traces marbling to 23.7% for those with modest degrees of marbling.

Campion and Crouse (1975) reported as little as 2.9% chemical fat was adequate for *longissimus* steaks to be acceptable in palatability. Savell and Cross (1989), after reviewing the role of fat on palatability, reached a similar conclusion that 3% fat in the *longissimus* muscle was sufficient for acceptable palatability.

Postmortem Aging. Bratzler (1971) and Korten (1972) reported tenderness of beef is influenced by a number of antemortem and postmortem factors, of which the length of time following harvest was included. Numerous researchers have documented that aging of beef improved tenderness (Tuma et al., 1962; Smith et al., 1978; Jones et al., 1991; Aalhus et al., 1992). Smith et al. (1978) concluded aging U.S. Choice beef carcasses for 11 days results in optimum tenderness, flavor and overall palatability for the majority of beef muscles. Eilers et al. (1996) found that tenderness of beef continued to improve as postmortem aging time was extended. Jones et al. (1991) concluded that at 4 days of postmortem aging, over 69% of steaks were unacceptable in tenderness; at 11 days, 26.2% were unacceptable. However, the optimum length of postmortem aging necessary for the greatest improvement in tenderness is cut-specific (Eilers et al., 1996).

During postmortem aging of beef, numerous changes, commonly referred to as proteolysis, occur in muscle; ultimately, these improve tenderness. Calpains (for a complete review, see Goll et al., 1992) result in proteolytic alterations of key structural proteins when meat is held at refrigerated temperatures (Dransfield et al., 1992; Goll et al., 1992; Koohmaraie, 1992; Uytterhaegen et al., 1994; Huff-Lonergan et al. 1996). Proteolytic degradation occurs in all skeletal muscle protein classes (sarcoplasmic, stromal, myofibrillar), but the degradation of myofibrillar (Goll et al., 1983; Tarrant, 1987; Huff-Lonergan et al. 1995, 1996), cytoskeletal (Taylor et al., 1995; Ho et al., 1996) and costamere (Taylor et al., 1995) proteins appears to be responsible for the majority of postmortem meat tenderization.

CHAPTER III

HEALTH OF GROWING AND FINISHING STEERS: EFFECTS ON PERFORMANCE, CARCASS TRAITS AND MEAT TENDERNESS

ABSTRACT

Costs for the treatment of respiratory disease among feedlot cattle are significant; however, limited research documents the impact of this disease complex on production losses and meat quality. Accordingly, 204 steers calves were used to evaluate the effects of respiratory disease during a 150-d finishing period on daily gain, carcass traits and *longissimus* tenderness. Steers were monitored daily for clinical signs of respiratory infection and medicated as needed. At harvest, lungs were evaluted for bronchopneumonia lesions in the anterioventral lung lobes (AVBP lesions) and lymph gland activity (non-active vs. active). Lung lesions were present in 33% of all lungs but were equally distributed between medicated (37%) and non-medicated groups (29%). Steers that were either medicated (n = 102) or had AVBP lesions (n = 68) had reduced ($P < .05$) final live weights, ADG, carcass weights (HCW), less external and internal fat and more desirable YG. Classification by lymph gland activity revealed that steers with lesions (n = 87), regardless of lymph gland activity, and those with active lymph glands (n = 9) had lower ($P < .05$) daily gains, lighter HCW, less internal fat and lower marbling scores than steers without lesions or steers with non-active lymph glands, respectively. Morbid steers, regardless of classification system, yielded more U.S. Standard carcasses than "non-sick" steers. No differences ($P > .10$) in *longissimus* shear force (WBS) values were evident, except that steaks from steers without lesions aged 7 d tended ($P = .05$) to have lower WBS values than steaks from steers with lesions. Overall, morbidity suppressed daily gains and carcass quality (increased the percentage of U.S. Standard) but improved YG as compared to "non-sick" steers. Classification of lung lesions by lymph gland activity was more predictive of production, carcass trait and meat tenderness differences than antemortem health evaluations.

(Key Words): Health, Morbidity, Performance, Carcass Traits, Tenderness.

Introduction

Cattlemen have long recognized the importance of calf health and its relationship to profitability. Respiratory complications account for over 90% of all clinical treatments during the first four to five weeks at the feedyard (Martin and Lumsden, 1987) and may continue throughout the finishing phase (Edwards, 1988; Martin et al., 1982). Economically, bovine respiratory disease (BRD) is the most important disease affecting feedlot cattle throughout North America (Church and Radostits, 1981; Yates, 1982; Martin et al., 1989). Perino (1992) reported that the costs attributable to the treatment of BRD are substantial.

McNeill et al. (1996) reported that "healthy" steers had higher ADG during the finishing period (2.93 vs. 2.78 kg), yielded 12% more U.S. Choice carcasses and realized more profit than "unhealthy" steers. Other workers (Martin et al., 1989; Morck et al., 1993) have reported that cattle treated for respiratory disease had lower daily gains than those not treated. Feedlot steers with lung lesions at slaughter had lower daily weight gains (Wittum et al., 1996; Bryant et al., 1996; Bryant, 1997) and a lower percentage of U.S. Choice carcasses (Bryant et al., 1996) than steers without lesions. The association of clinical and physiological health with other carcass traits and meat tenderness has not been investigated.

The current study was conducted to evaluate: 1) the effects of clinical health and 2) the effects of lesions associated with bronchopneumonia and temporal lung classification (lung lymph gland activity) on cattle performance, carcass characteristics and meat tenderness.

Materials and Methods

Feedlot Performance. Predominantly Charolais steer calves (n = 222) from a single source were transported to a commercial feeding facility in southwestern Kansas. Upon arrival, steers were weighed, vaccinated and dewormed, implanted with a combination implant containing 20 mg estradiol benzoate plus 200 mg progesterone and individually identified with both electronic identification tags and individual numbered ear tags. Animals were placed in a single pen where they were adapted to their high concentrate ration. On day 82 of the feeding period, steers were reimplanted with 120 mg trenbolone acetate plus 24 mg estradiol benzoate. Individual weights of steers were obtained on day 137 of the feeding period. On day 150, 108 steers were transported to a commercial packing facility for harvest; the remaining steers (107) were harvested on day 151. Feedlot daily gain was determined using the individual animal weights collected on day one (assumed to be a shrunk weight) and on day 137 (assuming a 4% gut fill) of the feeding period. Dressing percentage was calculated by dividing the hot carcass weight by the unshrunk individual weight obtained on day 137.

Antemortem Health Evaluation. During the total finishing phase, steers were monitored daily for clinical signs of respiratory infection. Rectal temperatures were obtained from each animal observed to have a respiratory disorder. Sick steers were treated using a pre-determined protocol developed by the consulting veterinarian and were maintained at the hospital for a minimum of three days. For statistical analysis, steers were categorized according to the number of times they were pulled for the treatement of respiratory disorders (none, once, twice or more). Cause of death was determined for the cattle that died during the finishing period and is shown in Table I. Two steers, deemed as "realizers" were marketed on days 75 and 82 of the finishing period. One steer was held for residue clearance at the conclusion of the finishing period.

Postmortem Health Evaluation. As steers were harvested, both ears were palpated for the presence or absence of implants as well as for the presence of abnormal tissue reactions around the implants. Liver pathology was monitored using the Elanco scoring system for abscesses (Brink et al., 1990). Lung lesions were recorded on a lung scoring sheet according to lesion type (gross classification) and the respective lobar location as described by Bryant (1997). Lesions that occurred in the cranial ventral lung lobes were classified as resulting from bronchopneumonia. Lobes with missing portions or whole lobes missing were classified as missing due to adhesions from previous pneumonia. As recommended by Bryant (1997), each lung was evaluated from both anterior and posterior views and lungs were categorized by a temporal classification scheme; lung lesions were classified as non-active or active, depending on the activity of lung lymph glands. Lesions from lungs with non-active lymph glands presumably occurred earlier in the finishing phase than lesions from lungs with active lymph glands.

Carcass Characteristics. After harvest, carcasses were chilled at 0°C for approximately 36 hours, after which USDA quality and yield grade (USDA, 1989) carcass characteristics were collected. The ribeye (10th through 12th rib) lip-on (IMPS 112A; USDA, 1988) was fabricated from the left side of each carcass, vacuum packaged and transported to Wichita, KS where samples were aged for five days at 2°C.

Longissimus Preparation. Samples transported to Wichita, KS were crust frozen for one hour prior to fabrication, after which a 1.3 cm thick *longissimus* slice was removed from the posterior end of each ribeye, completely denuded of all subcutaneous fat plus epimysial connective tissue and stored in a Whirlpack® bag at -20°C. Four additional 2.54 cm thick steaks were obtained, vacuum packaged and assigned to be aged at 2°C for 7, 14 or 21 days or serve as a spare. At the end of each assigned aging period, appropriate steaks were boxed, blast frozen and maintained at -40°C. Spare steaks were frozen after 7 days of postmortem aging.

Proximate Analysis. Proximate analysis of *longissimus* samples was performed in duplicate according to the procedures outlined by AOAC (1984). Samples immersed in liquid nitrogen were pulverized to a powder in a Waring® Commercial Blender (Model 34B122). A 3 g powdered sample was placed on 15 cm ashless filter paper, dried for 24 h at 100°C, desiccated for 1 h and re-weighed to determine percentage moisture. Following moisture determination, samples were placed in a soxhlet and extracted for 24 h with petroleum ether after which samples were dried at 100°C for 12 h, desiccated and re-weighed for determination of lipid content.

Cooking and Shear Force. Upon completion of the 21 day aging period, steaks were assigned randomly to one of eight cook days. Twenty-four hours prior to cooking, appropriate steaks were placed on metal trays, the vacuum was released and steaks were tempered at 4°C (AMSA, 1995); no more than 10 steaks were removed from the tempering cooler prior to cooking. Steaks were broiled at 177°C in an impingement oven to a final internal temperature of 70°C; temperatures were monitored with copper constantan thermocouples (Model OM-202, Omega Engineering, Inc., Stamford, Conn.). Individual weights of steaks were obtained prior to as well as following cooking for cook loss calculations. After steaks were cooled to 25°C, six cores (1.27 cm diameter) were removed parallel to the longitudinal direction of the muscle fibers. Shear force values were obtained on six cores from each steak that were sheared singularly using a Warner-Bratzler attachment to an Instron Universal Testing Machine (Model #4502, Instron, Canton, MS) moving at a crosshead speed of 200 mm/min. The peak force (kg) was recorded by an IBM PS2 (Model 55 SX) using software provided by Instron Corporation; the mean peak force for the six cores was analyzed as an objective measurement of tenderness.

Statistical Analysis. Data were analyzed separately for the effects of clinical evaluations and the classification of lung lesions at harvest using the Least Squares procedures (SAS, 1988). Because clinical evaluations consisted of non-treated cattle as well as cattle treated once and twice, contrasts were used to assess differences between non-treated versus treated cattle as well as those treated once versus twice. A similar approach was used to group cattle by temporal classification of lesions; lungs without lesions were contrasted to those with lesions, regardles of lymph gland activity, and lungs with non-active lymph glands were compared to those with active lymph glands. Upon obtaining a significant F-test, least squares means were used to partition differences in live, carcass traits and *longissimus* characteristics for steers with versus those without anterior ventral bronchopneumonia lesions. Probability values were reported as generated by SAS (1988). Cattle that died during the finishing phase (four), those shipped as "realizers" (three) and steers for which complete data were unavailable (eleven) were not included in any of the data analyses; the data set consisted of 204 cattle for which complete data were available and collected.

Results and Discussion

Mean, minimum and maximum values for selected live, carcass and *longissimus* characteristics are presented in Table II. Mean initial live weight for the steers used was 291 kg and final weight collected on d 137 was 517 kg; however, initial and final live weights ranged from 229 to 460 kg and from 395 to 608 kg, respectively. Average daily gain was 1.50 kg per day but ranged from .71 to 2.08 kg. Dressing percentage was near the industry average of 63.5% when calculated using the unshrunk individual weight collected on d 137 but ranged from 57.7 to 68.2%. The mean adjusted fat thickness was 1.11 cm, indicating that the cattle, on average, were extremely lean. As a result of being trim externally, internally and heavy muscled, mean yield grade was 2.6. Even though marbling score ranged from traces to modest, mean marbling score was 36 percentage points into the slight marbling category. However, despite the mean quality grade of U.S. Select, Warner-Bratzler shear force values were very low even after only seven days of postmortem aging.

Performance Traits. The effect of antemortem health on cattle performance and carcass attributes is presented in Table III. In the present study, exactly 50% of the steers involved were treated for respiratory disease during the finishing period. Wittum et al. (1996) reported 35% of steers were treated for respiratory disease either prior to weaning, in the feedlot or both; Wittum and Perino (1995) and Bryant (1997) summarized that 46.6 and 11% of observed steers had respiratory-related morbidity while in the feedlot, respectively. Although initial weights of steers used were not different (P = .59), steers clinically diagnosed as "sick" during the finishing phase (Table III) had lower ADG ($P < .02$) than non-treated steers (1.53 vs 1.47 kg/day). This resulted in 12.2 kg lighter carcass weights ($P < .01$) for the treated steers. Similar reductions in feedlot gain among cattle treated for respiratory complications have been demonstrated previously (Martin et al., 1989; Bateman et al., 1990; Morck et al., 1993; Wittum and Perino, 1995; McNeill et al., 1996). In contrast, other researchers (Cole et al., 1979; Jim et al., 1993; Griffin et al., 1995; Wittum et al., 1996) have reported that ADG did not differ among clinically "sick" versus "healthy" cattle. Bateman et al. (1990), Wittum and Perino (1995) and McNeill et al. (1996) reported that ADG was .06, .04 and .07 kg slower among calves treated for clinical BRD, respectively, compared to the .06 kg reduction in the present study.

Comparing steers "sick" once versus more than once, final weights did not differ (P = .21), but steers "sick" once gained at a faster rate than those "sick" twice (P = .04). Regression analysis revealed net gain was reduced by 6.43 kg (P = .002) for each day a steer was held in the hospital for clinical treatment of respiratory complications. A partial explanation for the reduced daily gains of "sick" steers may be a result of decreased feed consumption. Although feed intake on individual animals was not collected for the present trial, Sowell et al. (1996) reported that on average steers treated for clinical health symptoms spent 23% less time and made fewer trips to the feedbunk over a 32 d receiving period. The difference in "time-at-the-bunk" was even more pronounced during the first four days immediately following feedlot delivery; non-medicated steers spent 47% more time at the feedbunk (Sowell et al., 1996).

Anterior ventral bronchopneumonia (AVBP) lesions were evident among 33% of the calf-fed steers in the present study. Wittum et al. (1996) and Bryant (1997) reported pulmonary lesions were evident in 72 and 43% of all lungs evaluated at harvest, respectively. This difference in lung lesion incidence may be explained partially by the fact that in previous studies, all pulmonary lesions were included, whereas in the present study only those resulting from bronchopneumonia infections were counted. Wittum et al. (1996) reported that pulmonary lesions were evident among 78% of treated and 68% of untreated steer lungs. The frequency of AVBP lesions in the present study was similar among clinically treated (37%) and non-treated steers (29%).

Steers diagnosed with bronchopneumonia type lesions (Table IV) were lighter at the conclusion of the finishing period (*P* < .01) as a result of .14 kg decreased ADG (*P* < .01). Similar results were reported by Bryant (1997); ADG was .046 kg greater for cattle without AVBP lesions during the finishing period. Wittum et al. (1996) and Bryant (1997) concluded that ADG for beef cattle with lung lesions, regardless of type, was reduced by .076 and .034 kg, respectively.

Bryant (1997) concluded that if lesion age could be accurately determined, important knowledge would be gained about the pathogenesis and development of naturally acquired pneumonia. The frequency of lesions classified by the temporal system (lymph gland activity) revealed that non-active and active lymph glands were present in 34.3 and 2.9 percent of the lungs from non-treated steers, whereas 42.2 and 5.9 percent of lungs from treated steers had non-active and active lymph glands, respectively. The incidence of lung lesions, whether classified as AVBP-resulting or by temporal indices, in steers that did not receive medical attention indicates that 1) detection of BRD was not accurate, 2) lung damage occurred non-symptomatically or 3) BRD occurred prior to the finishing phase and resulted in permanent AVBP lesions on bovine lungs even after the cattle recovered from the disease (van der Mei and van den Ingh, 1987; Wittum et al., 1996).

The effect of temporally classified lesions on performance and carcass traits is presented in Table V. Initial steer weights were heavier for cattle detected with lung lesions ($P < .03$) as well as for those with active vs. non-active lymph glands ($P < .01$). However, cattle without lesions present at harvest had the heaviest final live weights ($P < .01$) as a result of the .15 kg higher daily weight gains ($P < .01$) than cattle with lesions. Steers with active lymph glands had .28 kg slower ADG than steers with non-active glands ($P < .01$).

Carcass Traits. Values for carcass traits are shown in Tables III, IV and V. Dressing percentage did not differ between "healthy" versus "sick" steers ($P = .31$); however, as a result of lighter final live weights (Table III), steers pulled for medication during the finishing period had 7.5 kg lighter carcass weights ($P < .01$). Carcasses from non-medicated steers were fatter both externally ($P < .01$) as well as internally ($P < .05$) and tended to have larger ribeye areas ($P = .12$) than carcasses from medicated steers. Consequently, steers not treated during the finishing period had higher U.S. yield grades than treated steers ($P < .04$) although ribeye area/100 kg hot carcass weight did not differ between the two groups ($P = .28$). Interestingly, cattle pulled and treated at the feedyard tended to have the most advanced skeletal maturity scores ($P < .10$) but the most desirable lean maturity scores ($P = .04$); as a result, no difference in overall maturity was observed between "sick" and "healthy" steers ($P = .67$). Marbling score appeared to be affected slightly by clinical health; non-medicated steers had slightly higher marbling scores than medicated steers (338 vs. 334; $P = .16$) which resulted in higher percentages of U.S. Choice and U.S. Select carcasses for non-medicated steers and more U.S. Standard carcass from medicated steers. These results support conclusions of McNeill et al. (1996) who reported that non-medicated steers produced a higher percentage of U.S. Choice carcasses than medicated steers.

Differences in carcass traits between steers sick once versus twice or more resembled differences between "healthy" versus "sick" steers. Steers pulled once had higher dressing percentages ($P < .07$) and yielded heavier carcasses ($P < .07$) that were fatter externally ($P < .01$) and internally ($P < .01$) than steers pulled twice or more. The fatter, heavier carcasses of the steers pulled once resulted in carcasses from twice pulled steers having more desirable yield grades than those pulled once ($P = .07$). No differences in ribeye area ($P = .30$), skeletal ($P = .22$), lean ($P = .39$) or overall maturity scores ($P = .87$) were detected between steers pulled once and those pulled twice. Although not statistically significant, cattle pulled twice tended to have lower marbling scores than those pulled once ($P = .15$). This difference in mean marbling score resulted in steers pulled more than once having the highest percentage of U.S. Standard carcasses.

As a result of lighter final live weights ($P < .01$), steers with a bronchopneumonia type lesion present at slaughter (Table IV) yielded lighter carcasses ($P < .01$) which had less external ($P = .04$) and internal ($P < .01$) fat as well as smaller ribeye areas ($P = .04$). As a result, carcasses with pneumonic lesions tended to have more desirable yield grades ($P = .06$) than the "healthy" cattle, similar to results reported by Bryant et al. (1996). Additionally, carcasses from steers with lung lesions had more youthful skeletal maturity scores ($P < .05$)

which resulted in more youthful overall maturity scores ($P = .10$). However, the carcasses from steers with lesions at slaughter tended to have lower marbling scores ($P = .13$) than those without lesions.

When lung lesions were grouped according to the temporal classification system (Table V), carcasses from steers without lesions had a higher dressing percentage than those with lesions ($P = .02$). Contrasts between non-affected and lesioned lungs revealed that carcasses from steers without lesions at slaughter were heavier ($P < .01$), had less external fat ($P = .13$), larger ribeye areas ($P = .15$) but smaller ribeye area/100 kg hot carcass weight ($P = .02$) and less kidney, pelvic and heart fat ($P < .01$) than steers with lesioned lungs. Non-active lymph gland vs. active lymph gland differences were noted in dressing percentage ($P < .01$), hot carcass weight ($P = .11$) and ribeye area/100 kg hot carcass weight ($P = .02$). Although no differences in skeletal, lean or overall maturity scores were evident ($P > .38$), carcasses from steers without lesions had a higher degree of marbling than those from steers with lesions ($P < .01$), while steers with lesions and no lymph gland activity tended to have more marbling than those with lesions and active lymph glands ($P < .06$). Steers that had lungs with active lymph glands produced a higher percentage of U.S. Standard carcasses at the expense of U.S. Choice and U.S. Select carcasses. Yield grade percentage differences were less dramatic than those observed for quality grade.

Longissimus Properties. Values for shear force, cook shrinkage and percentages of expected tender and tough steaks are presented in Tables VI, VII and VIII for clinical, AVBP and temporal classification evaluations, respectively. No differences in shear force values for steaks aged 7, 14 or 21 days were detected when classified by clinical evaluations or the presence of bronchopneumonia lesions. However, a small difference ($P < .06$) in shear force for steaks aged 7 d was detected between steaks from steers without lesions and those with lesions by the temporal classification system. Beyond seven days of aging, differences in shear force became nonexistent, regardless of temporal classification ($P > .15$). Cook shrinkage differences were apparent between steaks from non-medicated and medicated steers at day 21 ($P < .06$) as well as for steaks from steers pulled once versus twice ($P < .02$). *Longissimus* cook loss differences also were noted after 14 days of aging for steaks from steers with AVBP lung lesions ($P = .01$) and after 7 ($P = .03$) and 14 days ($P < .07$) for steers with temporal lesions; steaks from steers with lesions had consistently higher cook loss values as compared to those without lesions by the temporal system. No differences in the percentage of "expected tough" steaks were noted for any of the classification systems. All steaks had quite low shear force values.

No differences ($P > .15$) in percentage moisture (75.0, 75.3, 75.2%) or ether extractable lipid (2.6, 2.5, 2.2%) were found among *longissimus* tissue samples from steers never pulled and those pulled once or twice for medical treatment of clinically determined respiratory complications, respectively.

However, clinical health did appear to result in slightly lower percentage of ether extractable lipid for medicated vs. non-medicated steers (P = .13). Percentage moisture was higher among *longissimus* samples from steers with bronchopneumonia lesions than from steers without pneumonia-related lesions (75.0 vs. 75.4%; P = .05), but no difference in percentage intramuscular lipid was found (2.6 vs. 2.6%; P = .93). Temporal lesion classification revealed that steers with lesions had a higher percentage of moisture than those without lesions (75.0 vs. 75.4%; P = .01); moisture percentage tended to be higher for steers with active vs. non-active lymph glands (75.9 vs. 75.3%; P = .11). Percentage of intramuscular fat extracted by ether did not differ for steers without temporal lesions versus those with lesions. However, steers with active lymph glands at slaughter tended to have a lower percentage of intramuscular lipid than those with non-active lymph glands (2.0 vs. 2.6%; P = .13).

IMPLICATIONS

The results of our study indicate that morbidity is very detrimental to performance of beef steers during the finishing period and results in substantial reductions in carcass weight, fat deposition and ribeye area. The presence of lung lesions, especially lesions and active lymph glands, had much greater adverse effects on performance and carcasss traits than clinically diagnosed morbidity, reflecting the difficulty to detect morbidity. On a positive note, morbidity does not appear to be erode tenderness, even though it does appear to have an adverse effect on marbling score and U.S. quality grade.

The incidence of lung lesions, whether classified as AVBP-resulting or by temporal indices, in steers that did not receive medical attention indicates that 1) detection of BVD is not accurate, 2) lung damage occurrs non-symptomatically or 3) BVD may be occurring prior to the finishing phase, resulting in permanent AVBP lesions on bovine lungs even after the cattle recovered from the disease.

Based on results from the present study, classifying pulmonary lesions by a temporal system (lymph gland activity) may be more beneficial in detecting performance and carcass differences. Economically, strategies utilized at the onset of the finishing phase that reduce lung lesions may be beneficial as a result of improved daily gains and carcass traits.

TABLE I

CAUSE OF DEATH FOR STEERS USED IN DETERMINING THE EFFECTS OF CALF HEALTH DURING THE FINISHING PHASE ON PERFORMANCE, CARCASS TRAITS AND MEAT TENDERNESS

Date shipped	Head	Days-on-Feed	Cause of Death
11/27/96	1	25	Respiratory disease
1/12/97	1	71	Respiratory disease
2/23/97	1	113	Enterotoxemia
2/27/97	1	117	Bloat

TABLE II

MEAN, MINIMUM AND MAXIMUM VALUES FOR SELECTED LIVE, CARCASS AND MEAT ATTRIBUTES FOR STEERS (N = 204)

Trait	Mean	Minimum	Maximum	SD
Initial weight, kg	291	229	460	28.91
Weight at d 137, kg	517	395	608	40.20
ADG[a], kg/day	1.50	.71	2.08	.23
Dressing percentage	63.5	57.7	68.2	1.95
Hot carcass wt., kg	328.5	238.6	391.5	26.92
Fat thickness, cm	.83	.10	2.03	.34
Adj. fat thickness, cm	1.11	.20	2.03	.34
Ribeye area, cm^2	85.3	59.0	104.2	8.10
REA/100 kg HCW	26.1	16.6	33.1	2.26
KPH, %	2.3	1.0	3.5	.40
Yield Grade	2.6	1.3	4.9	.59
Maturity score[b]				
Skeletal	136.6	110.0	180.0	20.27
Lean	144.3	110.0	240.0	18.06
Overall	140.4	110.0	185.0	14.39
Marbling score[c]	335.6	210.0	550.0	42.81
Day 7 WBS, kg	3.7	2.3	6.2	.68
Day 14 WBS, kg	3.1	2.1	4.8	.47
Day 21 WBS, kg	2.9	2.0	4.7	.38
Day 7 cook loss, %	22.4	16.5	29.1	1.91

[a] ADG was calculated after a 4% pencil shrink was applied to individual steer weights obtained on d 137.

[b] Maturity score: 100 to 199 = "A", approximately 9 to 30 months of age.

[c] Marbling score: 500 = "modest[oo]", the minimum required for U.S Average Choice; 300 = "slight[oo]", the minimum required for U.S. Select; 200 = "traces[oo]", the minimum required for U.S. Standard.

TABLE III

PERFORMANCE AND CARCASS TRAIT VALUES STRATIFIED BY TIMES PULLED FOR MEDICAL TREATMENT OF CLINICALLY DETERMINED RESPIRATORY COMPLICATIONS

	Times Pulled[a]				Contrasts[b]	
Trait	**0**	**1**	**≥2**	**SE**	**0 vs P**	**1 vs ≥2**
Number of steers	102	89	13			
Initial weight, kg	293.2	287.6	293.2	5.23	.594	.521
Weight at d 137, kg	523.2	512.9	497.9	7.19	.013	.205
ADG[c], kg/day	1.53	1.49	1.35	.04	.012	.035
Dressing percentage	63.5	63.7	62.6	.35	.306	.056
Hot carcass wt., kg	332.2	326.6	311.8	4.80	.007	.062
Fat thickness, cm	.89	.81	.52	.06	.001	.004
Adj. fat thickness, cm	1.17	1.09	.76	.06	.001	.001
Ribeye area, cm^2	86.0	85.0	82.5	1.46	.117	.304
REA/100 kg HCW	25.9	26.1	26.7	.41	.280	.385
KPH, %	2.3	2.3	1.9	.07	.042	.002
Yield Grade	2.6	2.6	2.2	.11	.033	.074
Maturity score[d]						
Skeletal	142.8	144.9	151.5	3.26	.095	.219
Lean	139.4	134.4	129.2	3.64	.036	.390
Overall	141.1	139.7	140.4	2.61	.669	.867
Marbling score[e]	337.5	336.0	317.7	7.23	.161	.152
Quality Grade						
Choice, %	4.9	4.5	.0	3.73		
Select, %	82.4	83.2	76.9	6.93		
Standard, %	12.8	12.4	23.1	6.15		
Yield Grade						
1, %	13.7	19.1	38.5	6.85		
2, %	58.8	62.9	46.2	8.89		
3, %	26.5	18.0	15.4	7.50		
4, %	1.0	.0	.0	1.27		

[a] Times pulled is equivalent to the number of times steers were removed from the home pen for clinical treatment of respiratory related complications.

[b] Contrasts:
0 vs P = steers never medicated versus all medicated steers;
1 vs 2 = steers pulled once versus steers pulled for twice.

[c] ADG was calculated after a 4% pencil shrink was applied to individual steer weights obtained on d 137.

[d] Maturity score: 100 to 199 = "A", approximately 9 to 30 months of age.

[e] Marbling score: 300 = "slight^{oo}", the minimum required for U.S. Select.

TABLE IV

PERFORMANCE AND CARCASS TRAIT VALUES STRATIFIED BY THE PRESENCE OR ABSENCE OF LUNG LESIONS ASSOCIATED WITH BRONCHOPNEUMONIA

Trait	AVBP Lesion[a] Absent	AVBP Lesion[a] Present	SE	P =
Number of steers	136	68		
Initial weight, kg	292.1	288.0	3.03	.341
Weight at d 137, kg	525.4	500.6	4.05	.001
ADG[b], kg/day	1.55	1.41	.02	.001
Dressing percentage	63.6	63.3	.20	.344
Hot carcass wt., kg	334.2	317.0	2.70	.001
Fat thickness, cm	.86	.77	.04	.062
Adj. fat thickness, cm	1.14	1.04	.04	.039
Ribeye area, cm^2	86.2	83.7	.84	.037
REA/100 kg HCW	25.9	26.4	.24	.086
KPH, %	2.3	2.1	.04	.003
Yield Grade	2.6	2.5	.06	.057
Maturity score[c]				
Skeletal	138.6	132.5	2.11	.043
Lean	144.6	143.7	1.90	.723
Overall	141.6	138.1	1.51	.099
Marbling score[d]	338.8	329.1	4.48	.127
Quality Grade				
Choice, %	4.4	4.4		
Select, %	85.3	76.5		
Standard, %	10.3	19.1		
Yield Grade				
1, %	16.2	20.6		
2, %	58.1	63.2		
3, %	25.0	16.2		
4, %	.7	.0		

[a] The presence of anterior ventral bronchopneumonia (AVBP) lesions indicates that steers had clinical and asymptotic pneumonia.

[b] ADG was calculated after a 4% pencil shrink was applied to individual steer weights obtained on d 137.

[c] Maturity score: 100 to 199 = "A", approximately 9 to 30 months of age.

[d] Marbling score: 300 = "slight^{00}", the minimum required for U.S. Select.

TABLE V
PERFORMANCE AND CARCASS TRAIT VALUES STRATIFIED BY TEMPORAL LUNG LESION CLASSIFICATION

Trait	Temporal Lesion[a] none	non-active	active	SE	Contrasts[b] NO vs L	NL vs AL
Number of steers	117	78	9			
Initial weight, kg	289.4	290.0	315.0	6.00	.022	.014
Weight at d 137, kg	526.5	505.5	495.4	8.06	.001	.463
ADG[c], kg/day	1.58	1.43	1.17	.04	.001	.001
Dressing percentage	63.6	63.6	61.8	.40	.021	.008
Hot carcass wt., kg	334.8	321.5	306.9	5.44	.001	.111
Fat thickness, cm	.87	.79	.75	.07	.138	.710
Adj. fat thickness, cm	1.15	1.06	1.04	.08	.133	.891
Ribeye area, cm^2	86.6	83.4	85.2	1.68	.148	.531
REA/100 kg HCW	25.9	26.0	27.9	.47	.019	.016
KPH, %	2.3	2.2	2.0	.08	.002	.203
Yield Grade	2.6	2.5	2.4	.12	.213	.511
Maturity score[d]						
Skeletal	144.1	145.1	140.0	3.81	.670	.422
Lean	139.0	132.7	138.9	4.23	.427	.383
Overall	141.5	138.9	139.4	3.03	.410	.916
Marbling score[e]	340.1	332.6	303.3	8.89	.009	.051
Quality Grade						
Choice, %	5.1	3.8	.0	4.34		
Select, %	86.3	78.2	66.7	8.00		
Standard, %	8.6	18.0	33.3	7.05		
Yield Grade						
1, %	15.4	20.5	22.2	8.05		
2, %	59.0	60.3	66.7	10.3		
3, %	25.6	18.0	11.1	8.73		
4, %	.0	1.3	.0	1.47		

[a] Temporal lesion: none = no lung lesions of any type present; non-active = presence of a healed lesion from a previous respiratory infection; active = lesion and active lymph gland.

[b] Contrasts:
NO vs L = steers without lesions versus all with lesions;
NA vs AL = steers with non-active lesions versus active lesions.

[c] ADG was calculated after a 4% pencil shrink was applied to individual steer weights obtained on d 137.

[d] Maturity score: 100 to 199 = "A", approximately 9 to 30 months of age.

[e] Marbling score: 300 = "slight[00]", the minimum required for U.S. Select.

TABLE VI

WARNER-BRATZLER SHEAR AND COOK LOSS VALUES STRATIFIED BY TIMES PULLED FOR MEDICAL TREATMENT OF CLINICALLY DETERMINED RESPIRATORY COMPLICATIONS

	Times Pulled[a]				Contrasts[b]	
Trait	**0**	**1**	**≥2**	**SE**	**0 vs P**	**1 vs ≥2**
Number of steaks	102	89	13			
Shear force, kg						
7 day	3.6	3.8	3.7	.12	.402	.555
14 day	3.1	3.1	2.9	.08	.213	.110
21 day	2.8	2.9	3.0	.07	.169	.371
< 3.84 kg, %						
7 day	68.6	59.6	62.2	8.67	.621	.497
14 day	89.2	95.5	100.0	4.71	.068	.562
21 day	100.0	98.9	100.0	1.27	.654	.590
> 4.5 kg, %						
7 day	9.8	14.6	7.7	5.85	.816	.473
14 day	.0	1.1	.0	1.27	.654	.590
21 day	.0	1.1	.0	1.27	.654	.590
Cooking loss, %						
7 day	22.4	22.5	22.3	.35	.923	.754
14 day	22.2	22.9	22.5	.53	.384	.642
21 day	21.8	21.8	23.2	.35	.052	.013

[a] Times pulled is equivalent to the number of times steers were removed from the home pen for clinical treatment of respiratory related complications.

[b] Contrasts:
0 vs P = steers never medicated versus all medicated steers;
1 vs 2 = steers pulled once versus steers pulled for twice.

TABLE VII

WARNER-BRATZLER SHEAR AND COOK LOSS VALUES STRATIFIED BY THE PRESENCE OR ABSENCE OF LUNG LESIONS ASSOCIATED WITH BRONCHOPNEUMONIA

	AVBP Lesion[a]			
Trait	**Absent**	**Present**	**SE**	**P =**
Number of steaks	136	68		
Shear force, kg				
7 day	3.7	3.8	.07	.207
14 day	3.1	3.2	.05	.338
21 day	2.8	2.9	.04	.508
< 3.84 kg, %				
7 day	65.4	63.2	5.04	.757
14 day	94.1	89.7	2.75	.257
21 day	100.0	98.5	.73	.158
> 4.5 kg, %				
7 day	10.3	14.7	3.4	.359
14 day	.0	1.5	.7	.158
21 day	.0	1.5	.7	.158
Cooking loss, %				
7 day	22.3	22.3	.20	.211
14 day	22.1	23.3	.30	.010
21 day	22.0	21.6	.21	.134

[a] The presence of anterior ventral bronchopneumonia (AVBP) lesions indicates that steers had clinical and asymptotic pneumonia.

TABLE VIII

WARNER-BRATZLER SHEAR AND COOK LOSS VALUES STRATIFIED BY TEMPORAL LUNG LESION CLASSIFICATION

	Temporal Lesion[a]				Contrasts[b]	
Trait	none	non-active	active	SE	NO vs L	NA vs AL
Number of steaks	117	78	9			
Shear force, kg						
7 day	3.6	3.8	4.0	.14	.051	.350
14 day	3.1	3.1	3.2	.10	.511	.857
21 day	2.8	2.9	3.0	.08	.156	.184
< 3.84 kg, %						
7 day	68.4	60.3	55.6	10.17	.273	.781
14 day	94.0	89.7	100.0	5.50	.870	.267
21 day	100.0	98.7	100.0	1.47	.646	.604
> 4.5 kg, %						
7 day	10.3	12.8	22.2	6.80	.260	.410
14 day	.0	1.3	.0	1.47	.646	.604
21 day	.0	1.3	.0	1.47	.646	.604
Cooking loss, %						
7 day	22.2	22.7	23.3	.40	.030	.321
14 day	22.1	23.1	23.2	.61	.068	.898
21 day	22.0	21.7	22.2	.42	.880	.514

[a] Temporal lesion: none = no lung lesions of any type present; non-active = lung lesion that resulted from a previous respiratory infection but was healed at the time of slaughter; active = lesion and active lymph gland at slaughter.

[b] Contrasts:
NO vs L = steers without lesions versus all with lesions;
NA vs AL = steers with non-active lesions versus active lesions.

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APPENDIX

APPENDIX A

FREQUENCY PERCENTAGES OF ABSCESSED LIVERS STRATIFIED BY LIVER SCORE AND CLINICAL HEALTH EVALUATION

	Liver Abscess Severity[b]			
Times Pulled[a]	**Normal**	**A-**	**A**	**A+**
None, %	34.3	12.8	2.0	1.0
Once, %	31.9	8.8	2.9	.0
Twice, %	4.9	1.0	.5	.0

[a] Times pulled is equivalent to the number of times steers were removed from the home pen for clinical treatment of respiratory related complications.

[b] Normal = no liver abscesses; A- = one or two small abscesses or abscess scars; A = two to four well-organized abscesses; A+ = one or more large or multiple small, active abscesses with or without adhesions.

APPENDIX B

FREQUENCY PERCENTAGES OF ABSCESSED LIVERS STRATIFIED BY LIVER SCORE AND THE PRESENCE OR ABSENCE OF LUNG LESIONS ASSOCIATED WITH BRONCHOPNEUMONIA

	Liver Abscess Severity[b]			
AVBP Lesion[a]	**Normal**	**A-**	**A**	**A+**
Absent, %	25.5	5.4	2.0	.5
Present, %	45.6	17.2	3.4	.5

[a] The presence of anterior ventral bronchopneumonia (AVBP) lesions indicates that steers had clinical and asymptotic pneumonia.

[b] Normal = no liver abscesses; A- = one or two small abscesses or abscess scars; A = two to four well-organized abscesses; A+ = one or more large or multiple small, active abscesses with or without adhesions.

APPENDIX C

FREQUENCY PERCENTAGES OF IMPLANTS STRATIFIED BY IMPLANT PALPATION AND CLINICAL HEALTH EVALUATION

	Implant Status[b]		
Times Pulled[a]	**Present**	**Absent**	**Abscessed**
None, %	43.1	4.9	2.0
Once, %	37.8	3.9	2.0
Twice, %	4.4	1.5	.5

[a] Times pulled is equivalent to the number of times steers were removed from the home pen for clinical treatment of respiratory related complications.

[b] Ears of all steers were palpated at slaughter to determine the status of exogenous hormone implants administered during the finishing period.

APPENDIX D

FREQUENCY PERCENTAGES OF IMPLANTS STRATIFIED BY IMPLANT PALPATION AND THE PRESENCE OR ABSENCE OF LUNG LESIONS ASSOCIATED WITH BRONCHOPNEUMONIA

	Implant Status[b]		
AVBP Lesion[a]	**Present**	**Absent**	**Abscessed**
Absent, %	26.5	4.4	2.5
Present, %	58.8	5.9	2.0

[a] The presence of anterior ventral bronchopneumonia (AVBP) lesions indicates that steers had clinical and asymptotic pneumonia.

[b] Ears of all steers were palpated at slaughter to determine the status of exogenous hormone implants administered during the finishing period.

APPENDIX E

VALUES AND COSTS USED FOR CALCULATING NET VALUE DIFFERENCES BETWEEN "SICK" AND "HEALTHY" STEERS

PURCHASE PRICE[a] ($/CWT)

≤ 500	$96.53
501 - 600	88.19
601 - 700	82.42
701 - 800	79.11
> 800	75.27

OTHER COSTS

FEED	$200/T
YARDAGE	$.05/d
INTEREST	9.0%

[a]1986 - 1995 averages
[b]1995 and 1996 averages

BASE CARCASS PRICE[b] (CHOICE YG3) = $105.00

PREMIUMS[b] ($/CWT)

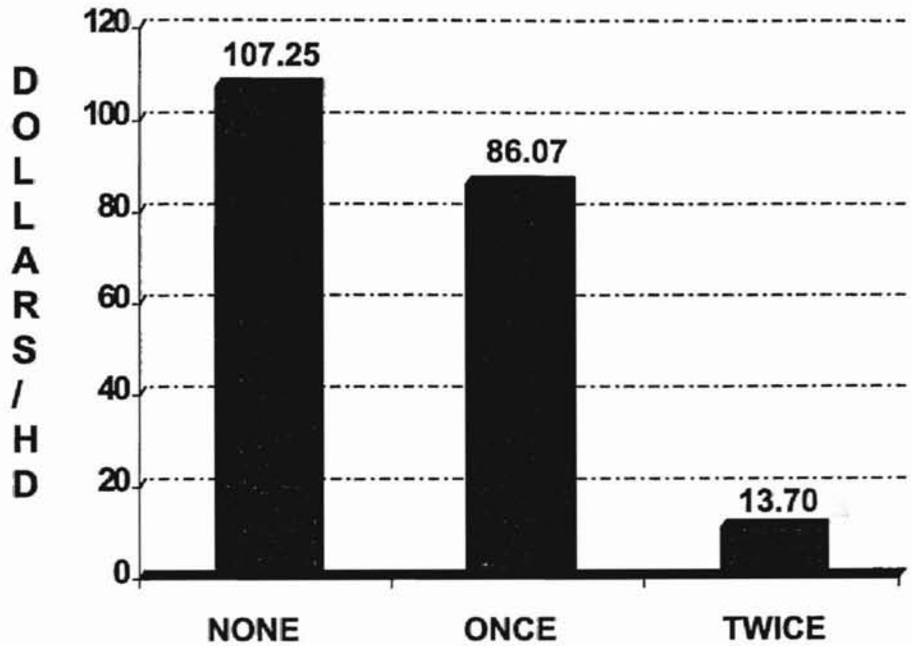
PRIME	+$5.00
PREMIUM CHOICE	+$2.00
YG1	+$3.00
YG2	+$2.00

DISCOUNTS[b] ($/CWT)

SELECT	($7.00)
STANDARD	($15.00)
YG4	($12.00)
YG5	($17.00)

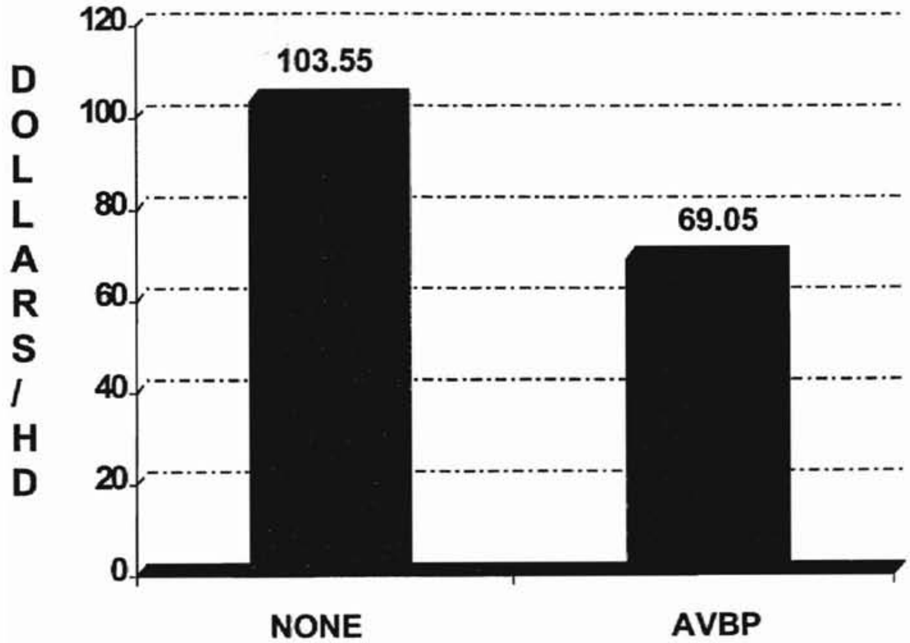
APPENDIX F

ABSOLUTE NET VALUE DIFFERENCES STRATIFIED BY TIMES PULLED FOR MEDICAL TREATMENT OF CLINICALLY DETERMINED RESPIRATORY COMPLICATIONS



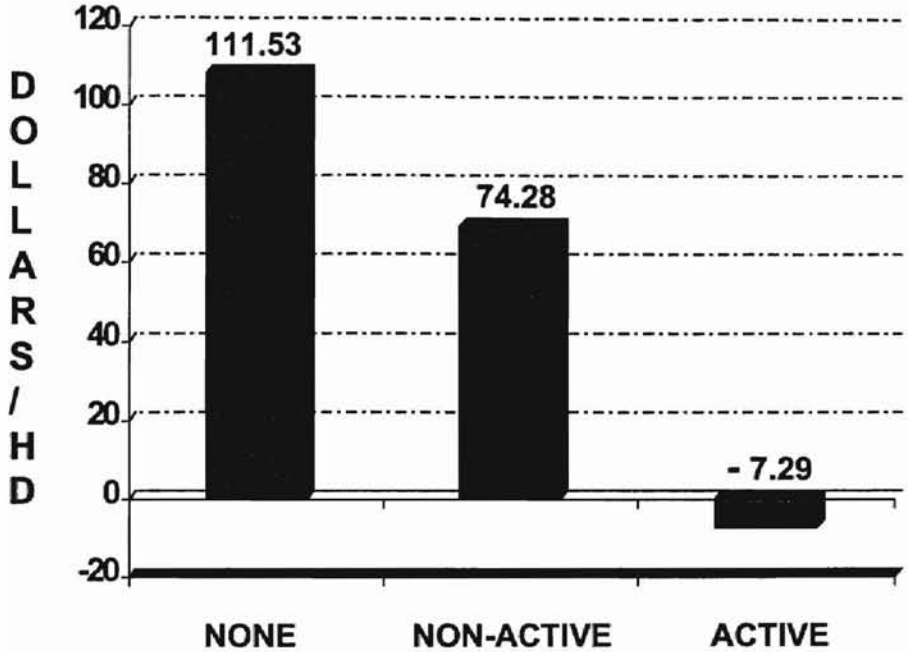
APPENDIX G

ABSOLUTE NET VALUE DIFFERENCES STRATIFIED BY
THE PRESENCE OR ABSENCE OF LUNG LESIONS
ASSOCIATED WITH BRONCHOPNEUMONIA



APPENDIX H

ABSOLUTE NET VALUE DIFFERENCES STRATIFIED
BY TEMPORAL LUNG LESION CLASSIFICATION



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