

GROSS PATHOLOGY MONITORING OF CATTLE AT SLAUGHTER

by

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B.S., Kansas State University, 2008  
M.S., Kansas State University, 2010

AN ABSTRACT OF A DISSERTATION

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Department of Diagnostic Medicine/ Pathobiology  
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## Abstract

A series of studies were conducted in order to develop, test, implement, and utilize an objective and comprehensive gross pathology scoring system for cattle at slaughter. Individual lung, liver, and rumen gross pathology data was collected from 19,229 head of cattle and corresponding individual pre-harvest and carcass data for a subset of 13,226 head.. Across the entire population 22.6% and 9.8% of cattle displayed mild and severe lesions, respectively. Severe lung lesions at the time of slaughter were associated with a decreased ADG of 0.07 kg/ day and a carcass weight 7.1 kg less than that of their cohorts with no visible signs of pulmonary BRDC lesions ( $P < 0.01$ ). Overall, 68.6 % of cattle observed had normal livers, free from abscesses and other abnormalities. Cattle with a severe liver abscess at the time of slaughter were associated with a 0.10 kg/day during the feeding period ( $P < 0.01$ ). Of cattle severely affected by liver abscesses (A+, 4.6%), 14.9% also displayed severe BRDC lung lesions and 28.3 % of cattle displayed mild BRDC lung lesions. Rumenitis lesions were observed in 24.1% of the overall study population. Severe rumenitis lesions were associated with a significant decrease in average daily gain and carcass weight (0.03kg/day and 2.20 kg, respectively,  $P < 0.01$ ). The system was also implemented on a population of cull cows at a commercial abattoir in the Great Lakes region of the U.S. (n=1,461; 87% Holstein, 13% other cows). Severe liver abscesses, were observed in 18.5% of cull cows at slaughter. Severe rumenitis lesions or rumenitis scars were observed in 10% and severe BRDC lesions were observed in 10.3% of the population. A prospective study of a commercially available, direct fed microbial oral drench of *Megasphaera elsdenii* (NCIMB 41125) was conducted in 4,863 head of yearling feeder cattle. No significant effects of treatment were detected for final live weight (599 vs. 601 kg;  $P=0.79$ ) or hot carcass weight (386 vs. 387

kg  $P=0.81$ ) for Con and M.e., respectively. Fourteen point two percent and 14.0% of Con and M.e., respectively displayed a liver abscess of varying severity at the time of slaughter. Overall, 8.27 and 7.96% % of Con and M.e. cattle were observed with an altered rumen epithelial health status. The ordinal odds ratio of a M.e. treated animal having a more severe liver abscess score or rumen health score was not significant (Estimate: 0.96, 95% C.L. 0.733-1.259,  $P=0.771$ ; Estimate: 1.01, 95% C.L. 0.625-1.63  $P=0.96$ , respectively.) Comprehensive monitoring of gross pathology at slaughter is commercially plausible and provides valuable data for veterinarians, nutritionists and management personnel.

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## **Dedication**

I wish to dedicate this work to my friend, Mr. Chris Gruber. You will be forever missed by those of us who had the honor and privilege of having you in our lives; your memory as a wonderful father, friend, coworker, and mentor will live on perpetually in our hearts.

# Chapter 1 - Review of the Literature

## Bovine Respiratory Disease Complex Pulmonary Lesions

### *General*

Bovine Respiratory Disease Complex (BRDC) is among the most prevalent and deleterious diseases affecting cattle production both in the U.S. and globally<sup>1,2</sup>. Total annual costs to the U.S. beef industry have been estimated to be approximately \$4 Billion when taking into account animal and production losses as well as prevention and treatment costs<sup>1</sup>. It has been estimated that BRDC accounts for 70 to 80% of total morbidity and 40 to 50% of total mortality in North American feedlots<sup>3,4</sup>. Though technology continues to advance in order to combat the troublesome disease, the most current National Animal Health Monitoring Survey reported that 15.5% of cattle in large feedlots (over 1,000 head capacity) were treated for the disease<sup>5</sup> and mortalities have actually been shown to increase over time<sup>6</sup>.

The disease itself is a result of a complex, multifactorial, causal web that, in the field, is not usually the result of a single necessary and sufficient cause. Several pathogens are implicated in the disease that include both viral (bovine herpes virus-1, bovine viral diarrhea virus (BVDV), parainfluenza-3 (PI<sub>3</sub>), bovine respiratory syncytial virus (BRSV), and bovine coronavirus) and bacterial (*Mannheimia haemolytica*, *Pasteurella multocida*, and *Histophilus somni*) infectious agents as well as *Mycoplasma spp*<sup>7,8</sup>. However, host and environmental factors may be equally important<sup>9</sup>; multiple investigations have indicated that stressful management practices such as weaning, castration, dehorning, commingling<sup>10</sup>, transportation<sup>11</sup>, inclement weather, and



nutritional stress or metabolic disease have the propensity to contribute greatly to the pathogenesis of the BRDC<sup>12-14</sup>.

### ***Pathoetiology***

Gross lung lesions at slaughter are the result of a cascade of events that ultimately lead to a structural change visible to the naked eye. Gross lesions occur as a result of pneumonia which can be the result of infection by the above mentioned viruses (alone or in combination with one another) as well the common bacterial pathogens *M. haemolytica*, *P. Multocida*, *H. Somni*, or *M. bovis*<sup>15, 16</sup>; however, several agents may produce similar gross lesions<sup>8</sup>.

In general, there are 4 steps that occur during a viral infection of the bovine respiratory tract 1) the upper respiratory tract is damaged and the mucociliary clearance function is altered which allows for bacterial growth, attachment, and colonization. 2) tracheal mucosal epithelial damage which further compromises the function of the mucociliary sweep and allows for bacterial growth, attachment, and colonization deeper into the respiratory tract 3) viral damage and depletion of macrophages and neutrophils which are responsible for the brunt of host immune function and phagocytosis and 4) damage and depression of humoral (B-Cell) and cell mediated (T-Cell) immune response<sup>8</sup>.

Bacterial pneumonia often follows in the wake of a viral infection, but often progresses along a similar pathogenic pathway that involves upper respiratory (nasopharyngeal) colonization, inhalation of aerosolized droplets which contain the pathogenic bacteria, bronchoalveolar colonization, host immune response, and pathogen evasion and damage to the host immune response<sup>17</sup>. *M. haemolytica* type 1 is typically the most common bacteria isolated in cases of acute fibrinous pleuropneumonia and therefore likely responsible for most of the severe gross

lesions observed at slaughter; however *P. multocida* is also a primary isolate in many bronchopneumonia cases<sup>18</sup>.

The numerous virulence factors associated with *M. haemolytica* ultimately lead to its ability to colonize and induce permanent structural changes in the bovine lung<sup>19,20</sup>: Leukotoxin, lipopolysaccharide (LPS), capsular components, outer membrane proteins, neuraminidases, and proteases are all important virulence factors associated with *M. haemolytica* infection and the pro-inflammatory cascade which results in much of the grossly visible pathology.

In general, the development of pulmonary lesions at the hands of *M. haemolytica* occurs in 4 indistinct and overlapping phases: pre-pneumonia, pulmonary consolidation, localized inflammation and spread, and expansion of pneumonia<sup>21</sup>. The major event of the pre-pneumonic stage occurs when *M. haemolytica* proliferates in the upper respiratory tract which leads to the initial step of pneumonia, the colonization of the bronchoalveolar junction. The bacteria are then able to colonize and begin to produce the above mentioned virulence factors in large enough quantities to induce a localized inflammatory response (lobular bronchopneumonia). At this stage, the lung lesion appears firm and dark red (liver-like). If an adequate host response is not mounted or an intervention is not applied at this point of the pathogenesis, the pneumonia will likely continue to expand. When bacteria complete their life cycle, LPS is released which further exacerbates the host inflammatory response. If this response is no longer confined to transmission through the airways, but instead travels through the interlobular septae and interstitium (lobar bronchopneumonia) it is likely that permanent structural and functional damage will occur. As a result of the extensive damage, the entire affected area of lung parenchyma turns from the normal healthy pink appearance to a dark red with a large amount of atelectasis. Pus formation and subsequent abscessation may occur. During resolution of the lung

parenchyma, large amounts of fibrin and fibrinous fluid are formed and pleural adhesions may develop.<sup>21</sup>

General gross findings include consolidated and/or collapsed lung parenchyma, focal or diffuse pleuritis, fibrinous adhesions, thoracic adhesions, abscesses, fibrosis, emphysema, and hemorrhage and are most frequently observed in the (right) cranial ventral lung lobes<sup>22</sup>.

### *Observation at Slaughter*

Multiple investigations have reported the occurrence of lung lesions at slaughter in cattle. In a population of 469 steers, Wittum et al. (1996) reported an overall lung lesion prevalence of 72% with a total respiratory morbidity of 35%. Moreover, 68% of the cattle not treated for BRDC during their lifetime displayed lung lesions at slaughter and 72% of those cattle treated for BRDC during their lifetime displayed lung lesions at slaughter. Additionally, pulmonary lesions at slaughter were significantly associated with a 0.076 kg reduction in average daily gain (ADG). Gardner et al. (1999) observed that in a population of genetically similar Charolais steers (n=204), 37% of cattle never treated for BRDC during the finishing phase had lung lesions at slaughter and only 48% of those cattle treated for BRDC during the finishing phase had lung lesions at slaughter<sup>23</sup>. Cattle with no lung lesions at slaughter were observed to have an 11% greater ADG than their cohorts with lung lesions present at slaughter. Variable effects of lung lesions and BRD treatment were observed on other performance and carcass characteristics; however, the data should be interpreted carefully as there was a relatively low *n* given the retrospective design of the study and the statistical model included no covariates to account for confounding effects. Nevertheless, a disparity between BRDC treatment and lung lesions was apparent.

Thompson et al. (2006) used similar methods to estimate the effect of respiratory disease on growth during early and late finishing periods in 2,036 head of South African feedlot cattle from 2 different feedlots<sup>24</sup>. Using the combined case definition for BRDC of lung lesions at slaughter as well and/or clinical identification in the feeding period, 52.5% of the study population were diagnosed with BRDC. However, lung lesions were present in 38.5% of cattle never treated for BRDC, 55.4% of cattle treated once for BRDC, and 66.7% of cattle treated for BRDC twice or more. Although the authors did observe that cattle treated for BRDC were significantly more likely to display pulmonary lesions at slaughter, the 52.5% overall prevalence of lung lesions was significantly greater than the 22.6% overall prevalence of BRDC treatments ( $P<0.01$ ). Their analysis of the associative performance effects included a multivariable regression model that allowed a more unbiased estimation of the associative effects of lung lesions and BRDC treatment and it was concluded that the overall associative effect of BRDC when utilizing the combined cases definition was a 0.024 kg reduction in ADG and an increase in 5 days on feed. Schneider et al. (2009) examined records from 5,976 steers and heifers from Southwest Iowa enrolled in the Tri County Steer Carcass Futurity database to evaluate the associative effects of BRDC on performance and carcass traits; however, observation of lung lesions at slaughter was only gathered on 1,665 head, of which, 61.9% had lesions present at slaughter<sup>25</sup>. Of cattle never treated for BRDC, 60.6% were observed with lung lesions at slaughter with the most common score (26.9%) being mild in nature. The authors reasoned that the disparity between lung lesions and BRDC treatment were likely a combination of subclinical BRDC cases not detectable using the field diagnosis methods, poor clinical diagnosis (i.e. missed sick animals), or cases of BRDC that occurred prior to the cattle entering the feedyard. These hypotheses were echoed by other authors that observed similar trends between lung

lesions and BRDC treatment records<sup>23, 24</sup>. A significant decrease in ADG ( $0.07 \pm 0.01$  kg), carcass weight ( $8.16 \pm 1.38$  kg), and marbling score ( $0.13 \pm 0.04$ ) was associated with BRDC, however the case definition included cattle that were either treated for BRDC during the feeding period or were observed with a lung lesion at slaughter, therefore, the specific associative effect of lung lesions at slaughter on performance were not ascertained.

Given the generation of published data reporting both BRDC treatment and lung lesions at slaughter, White and Renter (2009) aimed to form a model to estimate the diagnostic sensitivity and specificity of both traditional, clinical scoring and lung lesions at slaughter for diagnosing BRDC in beef cattle<sup>26</sup>. By utilizing Bayesian modeling techniques, they were able to estimate these values given that no true “gold standard” exists for BRDC diagnosis. Utilizing the data from the above studies<sup>23, 24</sup>, they estimated that the diagnostic sensitivity and specificity when utilizing clinical signs alone for BRDC diagnosis were 61.8% (97.5% probability interval: 55.7 to 68.4) and 62.8% (97.5% probability interval: 60.0 to 65.7), respectively. However, the use of lung lesions at slaughter, improved sensitivity to 77.4% (97.5% probability interval: 66.2 to 87.3) and specificity to 89.7% (97.5% probability interval: 86.0 to 93.8). Though the use of lung lesions at slaughter certainly led to an increase in diagnostic sensitivity and specificity, the downfall of lung lesions, as the authors noted, was that they are only able to be used in a *post hoc*, retrospective manor and offer little case specific value to veterinarians and animal health personnel that wish to improve their ability to diagnose BRDC cases in the field. However, utilizing lung lesions at slaughter to monitor health and management programs of cattle or as an objective outcome to evaluate the effect of interventions and management techniques is far superior to clinical observation alone.

## Rumenitis Lesions

### *Pathoetiology*

The primary role of the rumen is to serve as an anaerobic chamber and site of fermentation for the feedstuffs ingested by the bovine. In order for the ruminal microenvironment to remain homeostatic, fermentation products must be removed from the rumen at a rate somewhat proportional to their production. The primary products of fermentation (of carbohydrates) in the rumen are organic acids such as volatile fatty acids (VFA) and lactic acid. If the ratio between the amount of organic acids produced and the amount removed (either by further microbial metabolism or by host absorption) is increased, the ruminal pH will begin to fall. The buildup of organic acids in the rumen and the subsequent pH decline is a condition commonly known as ruminal acidosis. Ruminal acidosis may either be acute (pH < 5.0) or subacute (pH 5.0 to 5.6)<sup>27</sup>. Ruminal acidosis is usually the result of a sudden increase in the proportion of readily fermentable carbohydrates in the ration, irregularities in intake patterns and feeding behavior, or the lack of physically effective fiber in the diet, which decreases salivary buffering.

The rumen wall and its papillae are a major site for ruminal VFA metabolism and absorption and hence play a major role in ensuring homeostatic fermentation conditions and whole body energy balance, additionally, the ruminal mucosa serves as a protective barrier between microbes and the portal circulation<sup>28</sup>. However, when ruminal pH is decreased to non-physiological levels, the ruminal mucosa may be damaged by the high concentration of hydrogen ions and lead to a condition known as rumenitis.

Classical reports including Smith (1944)<sup>29</sup> and Jensen et al. (1954)<sup>30</sup> outline well the pathologic observations of the disease in cattle and offer an etiology almost identical to that which is described currently and affirmed by the latest molecular and microbiological techniques. Not restricted to the bovine, rumenitis has also been reported and investigated in other ruminant species including sheep<sup>31, 32</sup>, goats<sup>33, 34</sup>, white tailed deer<sup>35, 36</sup>, pronghorn antelope<sup>37</sup>, and American bison<sup>38</sup>.

Smith (1944) described several “levels” of rumenitis which in fact could be considered the first ruminal scoring system implemented at slaughter. The levels were as follows: 1) “Adhered contents” 2) “Denuded, depigmented, and eroded areas” 3) “active ulcerations” “covered with a thick, slimy pseudomembrane of diphtheritic exudate” 4) “clean ulcers in various states of healing” 5) “scars” 6) “papillomatous proliferation” 7) “clumped villi” and 8) “submucous nodules”. Smith also quantified and categorized these lesions in 1,807 cattle at slaughter along with the occurrence of hepatic abscesses. He observed that 42% of cattle that were found to have rumenitis lesions at slaughter had accompanying liver abscesses while only 9% of cattle without signs of rumenitis lesions had liver abscesses. It was this crude measure of association, absent of any accompanying statistical measures of correlation or error, that set the stage for what is known today as the rumenitis-liver abscess complex.

The papillae are the first structure affected by the low pH that accompanies ruminal acidosis. Generally, a sloughing of the stratum corneum is noted along with the appearance of non-differentiated keratinocytes on the surface of the rumen epithelium (the initial stages of ruminal parakeratosis)<sup>39</sup>. It has also been shown that in cases of acidosis where the stratum corneum is sloughed, cellular adhesion in the stratum spinosum is weakened, thereby potentially allowing

microbes and metabolites to freely diffuse across the epithelium and into portal circulation.<sup>39</sup> If the acidosis is severe enough, ulcerative lesions may be formed. These are usually confined to the ventral sac of the rumen<sup>30, 40</sup> but in this author's experience may occasionally be observed in the caudodorsal or caudoventral blind sacs of the rumen. Ulcerations may appear as round or oval shaped focal or multifocal lesions and may appear necrotic in nature (in some cases the result of a mycotic infection) or clean and in the process of healing with a bright red, smooth, shiny center with scar tissue forming on the peripheral borders<sup>29, 30, 40</sup>. Healed ulcerative rumenitis lesions appear as puckered scars or "stars", devoid of papillae, raised, and white in color.

### *Observation at Slaughter*

Few data exist on the prevalence of rumenitis in current cattle populations and in general, little attention has been given to the area by the veterinary or nutritional research community after the general adoption of the rumenitis-liver abscess complex pathogenesis model. As mentioned, Smith (1944) surveyed 1, 807 cattle at slaughter over the course of approximately 1 year at a commercial packing house in Denver, CO and reported an overall prevalence of 26%. Jensen et al. (1954) reported an overall rumenitis prevalence of 38% in a population of 1,535 cattle at slaughter. Weiser et al. (1966) fed 301 Friesian calves high concentrate diets (85% barley) supplemented with the antimicrobial chlortetracycline<sup>41</sup>. While they did observe a significant reduction in the prevalence of liver abscesses in the chlortetracycline treated cattle (11.8% vs. 28.2% in chlortetracycline vs. control, respectively  $P < 0.05$ ) there was no correlation between rumenitis lesions reported.



More recently, an overall prevalence of diffuse rumenitis lesions of 56.1% and an overall prevalence of focal mucosal scarring of 50.9% were reported for a population of 1,935 fed beef cattle at slaughter in South Africa<sup>42</sup>. Diffuse lesions were associated with a 0.060 kg and scars with a 0.046 kg reductions in ADG compared to their cohorts with no rumenitis lesions at slaughter. The authors also noted a wide variation in the prevalence of lesions within cohort groups; diffuse lesions ranged from 5.5 to 93.6% and scars from 3.3 to 72.3%.

Since rumenitis lesions are assumed to be direct sequelae of ruminal acidosis in most cases, they have the opportunity to be used as an objective indicator of the disease. Though systematic and periodic monitoring of rumenitis at slaughter would likely yield useful information for veterinarians, nutritionists, managers, and other parties involved in the health, welfare, and management of cattle, to this authors knowledge, no such instances are present. Scoring of the health of the rumen epithelium has, however, been used as an outcome of interest when investigating the effects of ruminal acidosis interventions. Leeuw et al. (2009) evaluated the rumens of 448 South African beef steers fed either a high or low roughage diet and treated with a live culture of a proprietary strain of the lactate utilizing bacterium *Megasphaera elsdenii* (NCIMB 41125) or a placebo<sup>43</sup>. The authors evaluated ruminal epithelium health on a 5 point categorical scale as follows: 0 = “long (> 1cm) papillae present, very tightly packed indicative of a high fibre diet”; 1 = “short papillae present but still very tightly packed”; 2 = “short papillae (<1cm), spaces between papillae and even small areas where no papillae were present and signs of damage by the presence of visible connective tissue”; 3 = “short papillae (< 5mm) with large areas where there were no papillae present and even spots where the papillae could be removed from the rumen wall and large areas with highly visible connective tissue present on the rumen

wall”; 4 = “very short papillae, large areas devoid of papillae while the remainder could be scraped off easily and large areas of connective tissue present”. No differences in rumen score was observed either between roughage level or *Megasphaera elsdenii* treatments. It should be noted however, that the authors analyzed ruminal health score data as if it was continuous data point and reported means which is not appropriate for categorical data on an ordinal scale.

Perhaps the most interesting and novel investigations carried out on the topic of rumenitis are those designed to elucidate the roll that the hair ingested during licking and grooming has on the occurrence of rumenitis. Fell et al. (1972) noted that sheep fed high concentrate diets similar to those fed to beef cattle did not develop rumenitis lesions resembling those in their bovine counterparts<sup>31</sup>. Hence, they hypothesized that hair fragments may serve as mechanical insults to the rumen epithelium and promote the development of rumenitis. To test this, they covered cattle with canvas coats and shaved any exposed haired areas. At slaughter, they observed that the rumen epithelium of the cattle now resembled that of the sheep fed a similar ration.

Furthermore, by adding 2 grams of clipped cattle hair to the diets of the sheep, they induced lesions characteristic of rumenitis observed in cattle. Histologic examination of ruminal epithelium showed fragments of hair embedded in the papillae and subsequent epithelial layers. It was observed that the rumens of sheep also contained fragments of wool, however penetration and injury to the ruminal epithelium was not apparent, perhaps due to the crimp associated with the wool fibers.

## **Liver Abscesses**

### ***General***

Liver abscesses in animals are formed as the result of entry, growth, and establishment of pyogenic bacteria<sup>44</sup>. Liver abscesses can occur in all ages and types of cattle, however most research attention has focused on fed beef cattle. The 2011 National Beef Quality Audit reported an overall prevalence of liver abscesses at slaughter in the U.S. fed beef cattle population to be 4.8% which was down from the previous 2005 National Beef Quality Audit prevalence of 13.9%, however, liver abscesses continue to be the leading cause for USDA liver condemnation<sup>45</sup>. As is the case with rumenitis, most instances of liver abscesses in cattle are assumed to occur as sequelae to ruminal acidosis.

### ***Pathoetiology***

The pathoetiology of liver abscesses in cattle have been described in great detail previously<sup>44, 46-49</sup>: Cattle fed diets containing large amounts of highly fermentable non-structural carbohydrates (concentrates) are at risk for developing ruminal acidosis due to the large quantity of organic acids (VFA and lactate) produced as a result of ruminal fermentation. Factors including lack of adaptation to a high concentrate ration, as well as variations in feed intake patterns and feeding behavior, and low amounts of physically effective fiber in the ration increase the risk of the development of ruminal acidosis. As a result of ruminal acidosis, the ruminal epithelium is exposed to a high concentration of hydrogen ions (low pH) and the epithelial layers which normally serve to protect the underlying portal circulation (the keratinized stratum corneum, stratum granulosum, and stratum spinosum) from ruminal metabolites and microbes are injured.

The breach in integrity of the epithelium allows microbes which are normally commensal in the ruminal microbiome to colonize the ruminal wall and elicit a host immune response. Once access to the ruminal wall is gained, they may form an abscess or emboli which can enter the portal circulation and translocate to hepatic capillaries where subsequent colonization and abscessation occurs within the liver parenchyma. The primary etiologic pathogen implicated in liver abscesses of cattle is *Fusobacterium necrophorum*, with *Arcanobacterium pyogenes* being of secondary importance. The prevalence of *A. pyogenes* in liver abscesses has been found to be influenced by tylosin feeding<sup>50</sup>, as well as cattle type (beef vs. dairy)<sup>51</sup>. Abscesses of the liver in cattle may be found in varying numbers and sizes; from 1 to over 100, and from < 1 cm to > 15 cm.<sup>44</sup>

### ***Observation at Slaughter***

Clinical diagnosis of liver abscesses in cattle is uncommon. In general, a sequela to the liver abscess that elicits clinical signs in an animal such as vagus indigestion syndrome<sup>52</sup> or caudal vena cava thrombosis syndrome<sup>53</sup> is required for diagnosis prior to slaughter. However, diagnosis via ultrasonography has been shown to be effective in cattle<sup>54-56</sup>. Given the difficult nature of clinical diagnosis, examining the liver at slaughter is the most common method employed for quantifying the incidence of liver abscesses in feedlot cattle.

Great volumes of data exist pertaining to observation of liver abscesses at slaughter that well outlines significant sources of variation for occurrence as well the associative effects on performance of cattle. At slaughter, the liver is exteriorized and separated from the rest of the visceral organs during the evisceration process. The liver is then placed on the offal chain table for inspection by USDA Food Safety Inspection Service personnel. This provides a convenient

period of time for inspection of the liver by interested parties for abscesses, parasites, or other abnormalities. Liver abscesses are routinely monitored as service for producers who utilize the macrolide antimicrobial, tylosin (Tylan, Elanco, Greenfield, IN), for the prevention of liver abscesses in feedlot cattle. The “Liver-check service” is provided by the animal health company Elanco which markets the feed additive Tylan and reports liver abscess data on 15,000-20,000 head of cattle per year<sup>57</sup>. The Elanco Liver-check system has also provided an objective scoring system for liver abscesses which is used industry wide and is defined as follows: 0 = no abscesses evident; A- = one or two small abscesses or scars; A = two to four well organized abscesses less than one inch (2.5 cm) in diameter; or A+ = one or more large active abscesses greater than one inch (2.5 cm) in diameter<sup>58</sup>.

The feeding of tylosin is by far the most widely and effective therapy used for the prevention of liver abscesses in feedlot cattle; a recent meta-analysis showed a 73 % decrease in the prevalence of liver abscesses when tylosin is fed, quantitatively a decrease in prevalence from 30% to 8%<sup>59</sup>. *Arcanobacterium pyogenes* / *Fusobacterium necrophorum* bacterin-toxoids have also been shown to be efficacious in significantly reducing the occurrence of liver abscesses at slaughter<sup>60</sup>,  
61.

Cattle type has been shown to significantly affect the prevalence of liver abscesses at slaughter; in a 4 year study of 4.6 million head, representing 31,341 pens, fed Holstein steers were observed to have the highest prevalence liver abscesses (23.4%), with minute numerical differences observed between beef breed heifers (13.5%) and steers (13.2%). Fed Holstein steers have been reported to display a greater propensity for digestive and metabolic disease and mortality than beef cattle<sup>62</sup>; however, it is likely that a majority of this disparity is a result of the

increased head days at risk associated with feeding Holstein steers to an acceptable market body composition rather than a direct breed or genetic factor.

Temporal and geographic variation in the prevalence of liver abscesses is also well defined and accepted within the industry<sup>63, 64</sup>; cattle slaughtered in the summer months are noted to have a greater prevalence of liver abscesses than their cohorts slaughtered in other seasons. This is perhaps related to the increase in amount or variation in feed intake that is observed in the spring months (i.e. “spring pop”) or also may be related to an increase in the amount of hair ingested by cattle licking their coats or the coats of their pen mates to groom and remove winter hair<sup>64</sup> which has shown the propensity to increase the occurrence of rumenitis<sup>31</sup>.

Liver abscesses, as discussed above, are usually assumed to occur as a result of ruminal acidosis, therefore, sources of variation in the incidence of ruminal acidosis also influence the incidence of liver abscesses. Decreasing the level of roughage in the diet has been shown to result in a general linear increase in the prevalence of abscesses at slaughter<sup>64</sup>. However, a lack of effect of roughage concentration on the prevalence of liver abscesses has also been observed<sup>65, 66</sup>. Other factors including diet adaptation, bunk management, feeding frequency, and bunk space have also been suggested to influence liver abscess occurrence<sup>47</sup>. Given the effect of ionophore antibiotics (e.g. monensin) on feeding behavior and rumen microbial population, one would reason some effect on the occurrence of liver abscesses would be apparent; however, a lack of effect has been consistently reported<sup>67-69</sup>.

The effect of liver abscess on performance and profitability can be substantial, depending on the severity and incidence. Not isolated to the cattle feeder, the packer also incurs costs due to liver abscesses, mostly as a result of direct losses associated with liver condemnations and trimming

of adhered abscess sites, however, intangible factors such as stoppage of the chain to allow for personnel to remove adhered livers also contribute.

Brink et al. (1990) conducted a series of investigations (12 in total) to elucidate the effect liver abscesses have on feed efficiency and performance of beef cattle<sup>70</sup>. A portion of their experiments showed no significant effects of the severity of liver abscesses on performance, however, the prevalence of liver abscesses was more than half (32.1%) of the prevalence reported in the second group of experiments (77.7%), in which, a significant effect of liver abscess score was noted for almost all performance outcomes measured (final live weight, carcass weight, feed intake, average daily gain, feed efficiency, and dressing percent;  $P < 0.10$ ). When contrasting the different severity scores, the most severe (A+) was the only score noted to significantly alter the performance outcomes compared to normal livers (0).

More recently, Brown and Lawrence (2010) conducted a retrospective analysis of 2 databases consisting of 3,936 head (slaughtered 2005 to 2009) with corresponding individual performance and carcass parameters (Database 1) and 72, 255 head of cattle (slaughtered 1998 to 2009) with corresponding carcass data. Overall liver abscess prevalence for both databases was reported as follows: A- = 5.0%, A = 2.6%, A+ = 6.1%. Associative effects of abscess scores on performance outcomes were variable to insignificant. This may be explained by the significant amount of confounding that likely existed within the data due to the lack of covariates included in the model. However, it was concluded that carcasses with varying severe degrees of liver abscesses were significantly less valuable than carcasses with normal livers ( $P < 0.05$ ).

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## **Chapter 2 - Prevalence, Severity, and Relationships of Multiple Gross Pathologies Measured at Slaughter in Beef Cattle<sup>1</sup>**

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## Abstract

A wide array of management tools and interventions exist within the beef industry to improve animal welfare and productivity; however, improved ability to monitor and assess the outcomes of these tools is needed. Therefore, a multifaceted system to observe beef cattle life-cycle health and well-being was designed and implemented to provide real time feedback data on cattle health and productivity. In beef cattle production systems, deficiencies in management most commonly manifest themselves as cases of Bovine Respiratory Disease Complex (BRDC) or nutritional disorders such as acidosis; therefore, lung, liver, and rumen gross pathology lesions present at slaughter were measured, and associations with performance determined. Investigators from Kansas State University collected individual lung, liver, and rumen gross pathology data from 19,229 head of cattle at commercial packing plants in Kansas and Texas; corresponding individual pre-harvest and carcass data were also obtained for a subset of 13,226 head outfitted with electronic identification ear tags. Associations between gross pathology lesions and outcomes of interest were modeled using systematically generated multivariable mixed effect models. Regression coefficients ( $\beta$ ) were used for estimation of lesion associative effects on continuous outcomes of interest and odds ratios ( $e^{\beta}$ ) reported for dichotomous outcomes. Across the entire population 22.6% and 9.8% of cattle displayed mild and severe lesions, respectively. Severe lung lesions at the time of slaughter were associated with a decreased ADG of 0.07 kg/day and a carcass weight 7.1 kg less than that of their cohorts with no visible signs of pulmonary BRDC lesions ( $P < 0.01$ ). Overall, 68.6 % of cattle observed had normal livers, free from abscesses and other abnormalities. Cattle with a severe liver abscess at the time of slaughter were associated with a 0.10 kg/day decrease in ADG during the feeding period ( $P < 0.01$ ). Of cattle

severely affected by liver abscesses (A+, 4.6%), 14.9% also displayed severe BRDC lung lesions, and 28.3 % of cattle displayed mild BRDC lung lesions. Rumenitis lesions were observed in 24.1% of the overall study population. Severe rumenitis lesions were associated with a significant decrease in average daily gain and carcass weight (0.03kg/day and 2.20 kg, respectively,  $P < 0.01$ ). No lesion score was associated with a significant change in the odds ratio of grading choice or better. Of cattle with mildly abscessed livers (A-), moderately abscessed livers (A), and severely abscessed livers, 20.6%, 21.6%, and 9.24 % displayed mild or severe rumenitis lesions at slaughter. Though the majority of the cattle in this population would likely be considered low-risk in many production systems, after adjustments for cattle with multiple lesions, 22.9% of cattle in the overall population were observed with a severe lesion (Lung, Liver, or Rumen). A collective gross pathology monitoring system is externally feasible within the industry and the 22.9% prevalence of severe lesions (Lung, Liver, or Rumen) indicates that significant opportunity exists to improve cattle health, well-being, and productivity. Data such as these may be used to provide benchmarks and support evidence based decisions concerning the implementation, modification, or removal of managerial practices and health interventions in beef cattle production systems.

## Introduction

Accurate and precise diagnosis of the most common diseases affecting fed cattle is challenging. In the case of bovine respiratory disease complex (BRDC) multiple investigations have elucidated disparities between the number of animals that were diagnosed with and treated for BRDC and those that displayed lung lesions at slaughter (Wittum et al., 1996; Gardner et al., 1999; Thompson et al., 2006a; White and Renter, 2009a). Using Bayesian estimation methods on previously published data to estimate sensitivity and specificity, White and Renter (2009) concluded that though the use of lung lesions as a diagnostic tool for BRDC was superior to that of a traditional clinical illness evaluation, lung lesions were not a true gold standard. Though diagnosis and treatment of BRDC is more prevalent than digestive disorders in US feedyards, 14.4% vs 1.9 %, respectively, (USDA, 2000) the latter is also an important issue but often does not involve individual diagnosis and treatment. The reported prevalence rates for liver abscesses (a sequelae to ruminal acidosis) in surveys of the US fed cattle population (13.9%; Garcia et al. 2008 and 4.8% McKeith et al., 2012) are again different than the treatment and diagnosis rates of reported by the USDA. Multiple reports have outlined the deleterious effects on performance and carcass characteristics when liver abscesses are present at slaughter (Brink et al., 1990; Nagaraja and Chengappa, 1998; Brown and Lawrence, 2010), therefore establishing the importance of controlling the causative factors.

Prior to the formation of an abscess in the liver, rumen parakeratosis and rumenitis occur allowing the pathogenic bacteria to migrate from the rumen into portal circulation (Kleen et al., 2003). Hepatic abscesses have been shown to be resolved into scars within 50 to 70 days after portal inoculation with *Fusobacterium necrophorum* (Itabisashi, 1987). However, once the

rumen epithelium is compromised and morphologic changes occur, the absorptive capacity of the affected tissue is lost, which may further exacerbate the accumulation of volatile fatty acids and or lactic acid (Kleen et al., 2003). Therefore, examining the rumen for gross pathological evidence of mucosal damage at slaughter may also be a valuable diagnostic tool for nutritional health (Thompson et al., 2008) . Quantification of rumen mucosal damage (lesions) at slaughter on the individual animal level has never been accomplished on the commercial scale. If ruminal lesion data is to be used as a tool for nutritional and dietary management, the ability to gather data on the commercial scale is required.

Besides influencing the welfare and performance of cattle, the occurrence of the above pathologies may negatively impact processes at slaughter. For example, fibrinous (lobar) bronchopneumonia may result in pleural adhesions of the lungs to the thoracic cavity. These adhesions often hinder the evisceration process and result in a stoppage of the processing chain in order for the packing plant personnel to complete procedure in the allotted space. Hepatic adhesions to the diaphragm, abdominal cavity, and other surrounding organs may occur in severely abscessed livers (Nagaraja and Chengappa, 1998). These abscesses and adhesions often hinder the evisceration process in addition to the economic loss of the liver to condemnation.

Given the mutual detriment of these lesions to the animal, the cattle feeder and the meat packer, it would be advantageous to all to monitor the lesion prevalence periodically to provide an objective indicator of the entire beef production process. However, the methods and scoring systems must be documented and consistent, data collection and communication must be able to be carried out easily and efficiently, and data must be compiled over time to establish baseline or “normal” ranges.

The objectives of this study were: 1). Determine the prevalence and relationships among multiple gross pathology lesions in beef cattle at slaughter 2). Develop and implement a system that collectively reports pre-harvest and performance data, carcass characteristics, and gross pathology prevalence and 3). Estimate the associative performance loss associated with the lesions measured.

## **Materials and Methods**

Animal care and use committee approval was not required for the methods used in this study as no live animals were utilized.

### ***General***

Collection and aggregation of data consisted of three steps: 1) Communication with cattle feeders to identify target cattle and their respective shipping schedules as well as communication with packing plant personnel to facilitate crew entry and cross-check shipping schedules and kill times with plant procurement personnel, 2) Collection of gross pathology data at the packing plant, and 3) Collection of pre-harvest and carcass data via cooperating feedyard and packing plant database systems.

Teams of trained investigators comprised of undergraduate, graduate, and veterinary students were dispatched to commercial packing plants to gather gross pathology data. Prior to gathering data, all personnel were trained utilizing a combination of self-study and instructor-led training material on all data collection procedures, however, attempts were made to utilize a homogenous crew of personnel as well as to maintain each crew member's respective assignment for the entirety of the data collection process.

Loin muscle area, marbling score, and 12<sup>th</sup> rib fat thickness were measured and calculated by video image analysis. Quality grade was assigned by USDA AMS Meat Grading and Certification Branch personnel. Individual carcass adjusted final live weight was calculated by dividing individual hot carcass weight by the lot level dressing percent.

Cattle were enrolled into the study via communication between the cooperating feedyards and Kansas State University personnel. Lesion prevalence and severity data were gathered on a total of 19,229 head of cattle from six commercial feedyards in Kansas [1] and Texas [5]. Cattle originating from Texas feedyards comprised 54.3% of the population and cattle from the Kansas feedyard made up the remaining 45.7%. Steers accounted for a slightly greater proportion of the population than heifers (53.5 % vs. 46.5%). The frequency distribution of initial date on feed is shown in Figure 1 and ranged from 11/16/2010 to 5/14/2012. Individual pre-harvest data was also collected on a subset of 13,266 head of cattle outfitted with electronic identification tags. Descriptive statistics of continuous variables for the subset are shown in Table 1.

### ***Gross Pathology Scoring***

Lungs scores were assigned by visually evaluating lungs as they passed by a single investigator at the offal table. Lungs were scored on a 3-point scale similar to that of Thomsson et al. (2006) Normal: No visible gross pathological evidence of lesions associated with BRDC, Mild: < 50% consolidation of any single lung lobe with lesions associated with BRDC, Severe: >50% consolidation of any single lung lobe with lesions associated with BRDC or any sign of pleural adhesion to the thoracic cavity. Although lesions occurring in any portion of the lung were noted and assigned a score, personnel were instructed in training materials to make a careful diagnosis

of the right cranial and middle lobes as a previous investigation has shown that > 86% of lesions are detected when only evaluating those anatomical locations(Epperson, 2003).

Livers were evaluated for the presence of abnormalities by a single investigator at the offal table. Hepatic abscesses were scored using a modified Elanco Liver Check System (Elanco, Greenfield, IN). Livers that were free from abscesses, parasites, or other pathological abnormalities were classified as Normal. An A- was assigned to livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars, an A designation was assigned to liver displaying 2 to 4 abscesses 2 to 4 cm in diameter, an A+ was assigned to livers displaying  $\geq 1$  abscesses > 4 cm in diameter or > 4 abscesses > 2cm in diameter. Abscesses adhered to the diaphragm, other organs or the abdominal cavity were noted and classified as A+A. Likewise, abscesses that were ruptured or “open” leading to the condemnation of all offal for the respective carcass were scored as an A+O. Livers with adhesions and ruptured abscesses were denoted as an A+AO. For the purposes of this report however, A+A, A+O, and A+AO scores were consolidated into the A+ category for prevalence and performance association data. The occurrence of other abnormalities including, liver flukes and other parasites, telangiectasis (of all degrees), and cirrhosis as well as livers condemned due to contamination or miscellaneous criteria were recorded.

The ruminal mucosa was evaluated for the presence of gross pathological lesions associated with the ruminal acidosis. Each rumen was identified with the respective carcass number of the animal from which it originated. Following evisceration, each rumen was drained of digesta and hung on the processing chain as per normal plant procedures. The area of the plant that was designated ruminal scoring to take place varied by plant location. Visual gross pathological



diagnosis was accomplished in teams of three; one crew member noted the plant carcass number and placed a tag on the esophagus. At the data collection area, one crew member read the identification number and communicated it to the crew member assigning lesion scores. Scores were assigned according to the following system: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult, Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae, Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae (Thomson, 1967). Rumens condemned by USDA inspection were not assigned a score. Likewise, if proper identification of the rumen was not accomplished, individual data were not retained and a designation of unknown was entered in the animal's record.

### ***Statistical Analysis & Data Management***

Data were stored and managed using Microsoft Excel for Windows 2010. Prior to analysis, a list of complete animal records were randomly selected to cross reference with hard copy records to assure valid data coalescence. Frequency distributions were calculated utilizing PROC FREQ of SAS (SAS Version 9.3, SAS Institute, Cary, NC). Associations between lesions and outcomes of interest were modeled utilizing systematically generated mixed models (PROC GLIMMIX; SAS Version 9.3, SAS Institute, Cary, NC) for each outcome. Outcomes of interest were established and random (G-Side) effects were defined to account for lack of independence within feedlot, initial lot, and harvest lot. Collinearity of independent variables was assessed and controlled for using calculation of Spearman rank-order correlation coefficients in a pairwise

manor; collinearity between two variables was declared at 0.9 (Dohoo et al., 1997). Univariate associations were evaluated among outcomes of interest and covariates. Linearity of continuous variables was determined by modeling quartiles or deciles of the variable as categorical data points. Covariates evaluated for each model included gross pathology lesions, sex, arrival weight, days on feed, metaphylaxis, BRDC treatment, sort group, initial month of arrival, and HCW. Covariates of interest were forced into the multivariable model to assess confounding based on > 20% change in effect estimate. Covariates were forced into the model in a stepwise fashion and fit was evaluated based on Bayesian Information Criteria (Dohoo et al., 2003). Regression coefficients ( $\beta$ ) are reported for estimation of lesion associative effects on continuous outcomes of interest and odds ratios ( $e^\beta$ ) reported for dichotomous outcomes. Differences among gross pathology lesion scores were evaluated using Tukey-Kramer adjustments for multiple comparisons of BYLEVEL adjusted marginal means.

## **Results and Discussion**

Across the entire study population, 22.6% and 9.8% of cattle displayed mild and severe lung lesions, respectively (Table 2.). In the subset of cattle with pre-harvest treatment and lung lesion data (n = 13,266), a similar percentage of severe pulmonary lesions was observed (9.45%) and mild lesions were observed in 26.12% of the cattle; however, only 2.1% of these cattle were treated for BRDC during the finishing phase. Of cattle treated for BRDC during the finishing phase, 44.7% displayed gross pulmonary lesions at slaughter. Among cattle not treated for BRDC in the finishing phase 35.6% displayed gross pulmonary lesions at slaughter. The reported prevalence of pulmonary lesions at slaughter have varied greatly; Bryant et al. (1999)

reported the prevalence of all types of pulmonary lesions to range from 33 to 77% in three populations of commercially fed cattle (n=599).

Severe lung lesions at the time of slaughter were associated with a decreased ADG of 0.07 kg and a HCW 7.1 kg less than that of their cohorts with no visible signs of pulmonary BRDC lesions ( $P < 0.001$ , Table 3 and Table 4, respectively). Intriguingly, mild BRDC lesions were associated with a slight increase in ADG and HCW versus cattle with normal lungs at slaughter ( $P=0.007$  and  $P<0.001$ , respectively). However, the odds of a carcass grading Choice or better was not significantly different among lung pathology score groups ( $P=0.99$ ).

A similar decrease in ADG of calves with lung lesions at slaughter was been reported by Wittum et. al. (1996), however, other reports have failed to find significant differences between the performance of calves with and without pulmonary lesions at slaughter (Schneider et al., 2009). The lack of continuity in these observations may be a result of several factors including variability in statistical power, management systems, animals, etc. However, case definition (i.e. Lesion scoring method) may also explain variability among reports, similar to the ability of clinical case definition of BRDC to influence morbidity and other health parameters. The pulmonary scoring system utilized in this experiment resulted in populations of cattle with significant differences in performance characteristics (Table 3.) and therefore, can serve as an objective indicator of animal health and welfare. Moreover, this system and others which are similar (Thompson et al., 2006b) are simple to implement in that there are only four outcomes possible for each set of lungs (three levels of pathology scores + Unknown). Applying this system at chain speed of a modern, commercial packing plant is more easily accomplished than a more complex system, yet it still delineates differences between biological indicators such as weight gain.

Overall, 68.6 % of cattle observed had normal livers, free from abscesses and other abnormalities (Table 2.) Of cattle severely affected by liver abscesses (A+), 14.9% also displayed severe BRDC lung lesions and 28.3 % displayed mild BRDC lung lesions. Among all liver abnormalities, the greatest performance loss versus normal livers was associated with the severe abscess and cirrhosis groups ( $P < 0.001$ ); however, liver cirrhosis was only observed in 0.2% of cattle over the entire study population. All final multivariable regression models for estimating associative performance effects contained each lesion as fixed effect covariates; hence regression coefficients ( $\beta$ ) may be summed to estimate the associative effects that could be expected for those cattle that displayed more than one lesion at the time of slaughter. For example, the 14.9% of cattle with severely abscessed livers which also presented severe pulmonary BRDC lesions could be expected gain 0.17 kg/day ( $0.10 + 0.07$  kg/day) less than their cohorts with normal livers and lungs.

Rumenitis lesions were observed most commonly on the ventral floor of the ventral sac, however lesions were occasionally found on the ventral floor of the caudodorsal blind sac as well.

Rumenitis lesions were observed in 24.1% of the overall study population (Table 2.). Current data reporting the prevalence and severity of rumenitis lesions in beef cattle is scarce. In one South African report, active or unhealed lesions were observed in 56.1% of cattle and healed lesions or “stars” were observed in 50.9% of cattle, however it was noted that great variability existed within cohort groups; prevalence of stars ranged from 3.3% to 72.3% and prevalence of active lesions ranged from 5.5% to 93.6% among cohort groups.

Of cattle with mild and severe rumenitis scores, 32 % had a liver abscess and 19 % of cattle with normal rumens had a liver abscess. Jensen et al. (1954) reported a high statistical correlation

between the occurrence of liver abscesses and ruminal pathology where the percentage of cattle with a liver abscess given a ruminal lesion was present was nearly double that of the percentage of cattle with a liver abscess given a normal rumen (41% vs. 23 %, respectively.) The magnitude of difference observed in the present study was not equal to that observed by Jensen et al. (1954) however, the difference is likely attributed to several factors. In this experiment ruminal gross pathology diagnosis was done at “chain speed” in a commercial U.S. slaughter plant with > 300hd/hr kill capacity. In order to model the associative effects rumenitis lesions, it was necessary to accomplish individual identification of each rumen so that it may be matched to individual animal. When the validity of this identification was in question, the standard operating procedure for this procedure dictated that the investigator score the rumen as an “Unknown”. Furthermore, if the rumen and/or the entire offal train was condemned by USDA inspection due to extensive adhesions or a ruptured abscess, the rumen was never presented to the investigators for pathologic examination and later marked as “Unknown” in the respective animal’s records. In fact, 53.0% of the cattle with severely abscessed livers received rumen scores of “Unknown”.

Classical reports have outlined the pathogenic etiology of the rumenitis-liver abscess complex by correlating the occurrence of ulcerative rumenitis lesions with hepatic abscesses in cattle (Smith, 1944; Jensen et al., 1954). This hypothesis of the pathogenic mechanism was later solidified and supported by the establishment of a strong genetic connection between the isolates of the causative agent, *Fusobacterium necrophorum*, in hepatic abscesses and the rumen wall of the same animal (Narayanan et al., 1997; Tadepalli et al., 2009). Given the accepted pathogenesis of the rumenitis-liver abscess complex, it is likely that many of the rumens which were condemned

as a result of severe liver abscess adhesion and/or rupture and therefore not scored, exhibited rumenitis.

Though there are logistic challenges to conducting pathologic examination of the rumen at chain speed in a modern U.S. packing plant, there are several advantages to including rumen lesion data in conjunction with liver abscess data when monitoring ruminal health in a production system or evaluating interventions. As stated, liver abscesses may heal within 50 to 70 days after the initial infection (Itabisashi, 1987) resolving into sterile fibrous scars (Scanlan and Hathcock, 1983). Therefore, hepatic abscesses formed in the initial stages of the feeding period may present as small unremarkable scars by the time cattle are sent to slaughter. Rumenitis lesions however, do not heal to the same degree of resolution and are thought to appear as puckered scars devoid of papillae (Thomson, 1967) permanently. Therefore rumenitis lesions may serve as “timeless” pathological sequelae and indicators of past chemical insults to the ruminal epithelium.

Mild rumenitis lesions were not associated with a significant change in ADG relative to Normal ( $P = 0.19$ ), however, Severe rumenitis lesions were associated with a significant decrease in ADG relative to Normal rumens (0.03 kg/day,  $P < 0.001$ ). This observation differs numerically from Thompson et al. (2008) who reported a decrease in gain of 0.046 to 0.060 kg/day in South African feedlot cattle when a ruminal mucosal lesion or scar was present at slaughter. This difference is likely be explained by the difference in management techniques and cattle between South African and U.S. High Plains beef production systems.

A significant depression in carcass weight (2.20 kg) was also associated with severe rumenitis lesions compared to Normal ( $P < 0.01$ ). The probability of grading choice or better however, was

not significantly associated with any level of ruminal lesion score (Fixed Effect  $P = 0.16$ ). The association of severe ruminal lesions with a performance loss while statistically accounting for the influence of liver abscesses, suggests that rumenitis acts as an independent antagonist to cattle health and performance rather than just supporting the pathogenesis of hepatic abscesses.

The population utilized in this investigation was composed mainly of yearling cattle that were exposed to similar management systems and were in general at a low-risk for developing BRDC. Future research should include evaluations of pathology in populations of high-risk, Holstein, or Mexican origin cattle which are exposed to a differing set of risk factors, or exposed to risk factors for a differing period of time.

The collective measurement of lung, liver, and rumen pathology at slaughter provides valuable information on the health and welfare of feedyard cattle. Results of this project show a highly significant relationship between lung, liver and rumen lesions and reduced performance, *and* that the effects are additive. Though the majority of the cattle in this population would be considered low-risk in many production systems, after adjustments for cattle with multiple lesions, 22.9% of cattle in the overall population were observed with a severe lesion (Lung, Liver, or Rumen) and therefore reduced performance. Hence, substantial opportunity exists for the improvement of health and productivity through changes in management with the goal of reducing the causes of lung, liver and rumen lesions.

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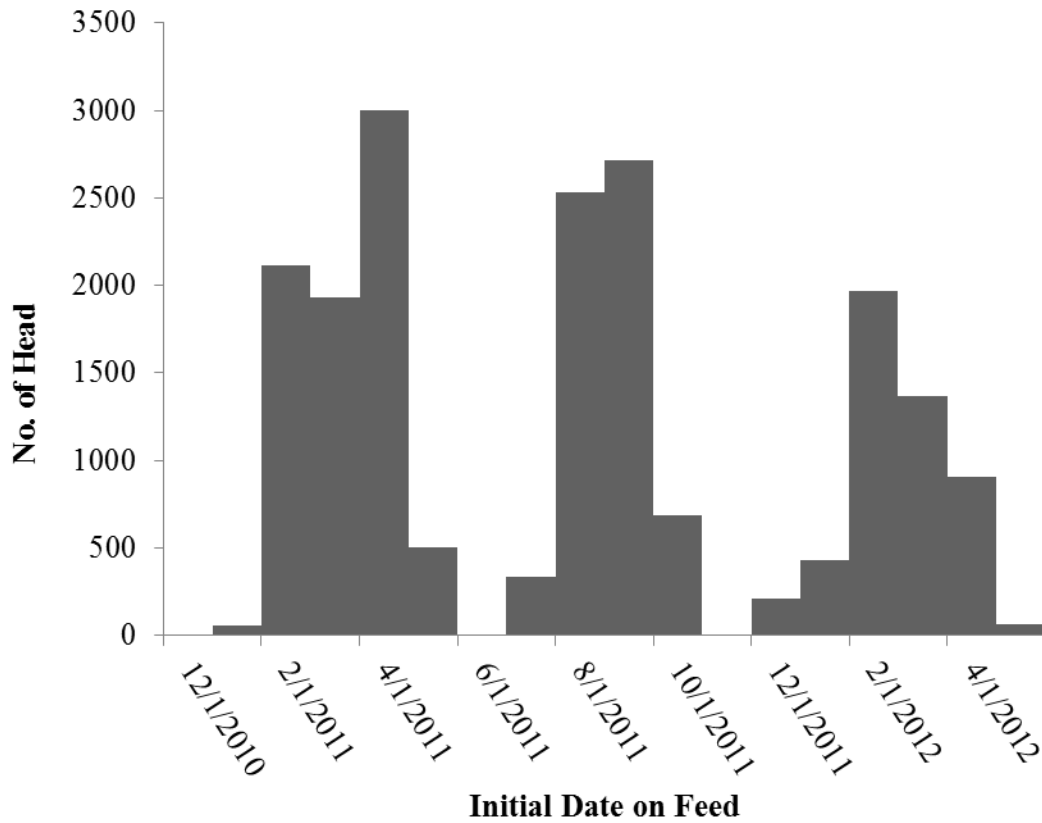
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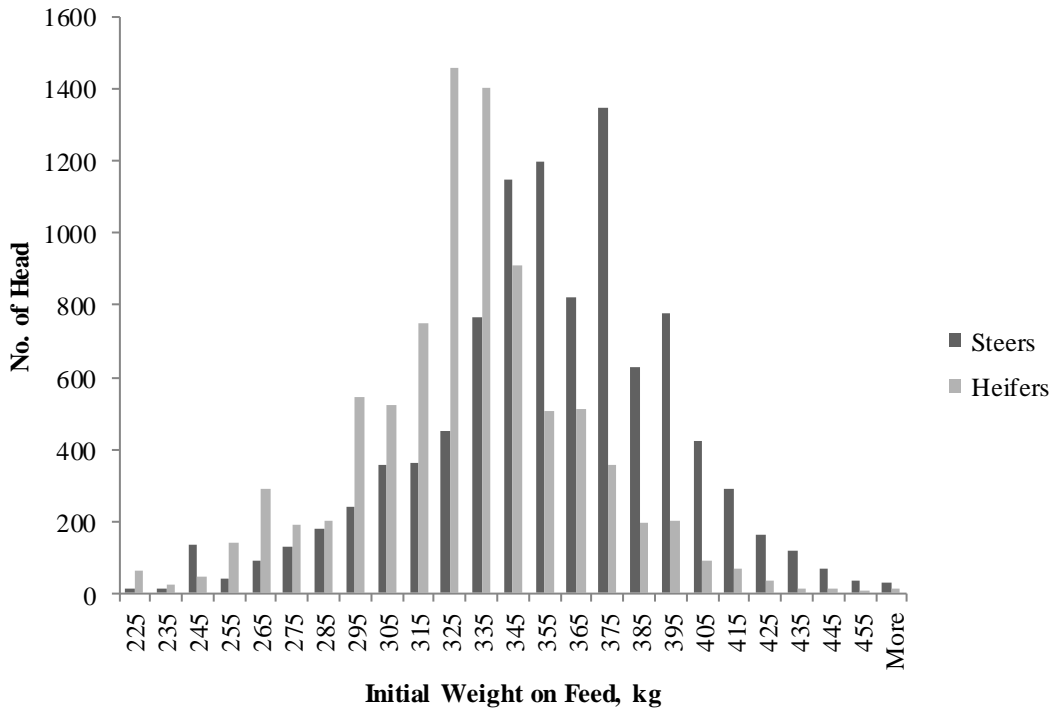
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**Figure 2-1. A histogram displaying the frequency distribution of initial date on feed of the study population. Median initial date on feed 7/25/2011. n=18,813**



**Figure 2-2 A histogram displaying the frequency distribution of the initial weight on feed for steers and heifers. Mean initial weight on feed for steers  $352 \pm 39$  kg. Mean initial weight on feed for heifers  $324 \pm 35$  kg.  $n = 18,367$ .**



**Table 2-1 .Descriptive statistics of continuous variables of feedlot cattle from three U.S. High Plains Feedyards used for modeling the associative effect of multiple gross pathology lesions at slaughter.**

Variable	n	Mean	SD	Minimum	Maximum
Arrival BW, kg	13,122	344	42.1	146	571
Final Weight, kg	13,266	584	59.7	343	795
Hot Carcass Weight, kg	13,266	373	39.0	223	525
LM area, cm <sup>2</sup>	13,258	34.94	4.43	18.54	56.64
12 <sup>th</sup> Rib Fat Thickness, cm	13,258	1.23	0.427	0.10	3.25
Marbling Score	13,258	443.9	87.94	222	919
Yield Grade	13,266	2.9	0.78	0	6.0
Days on Feed	13,266	156	26.5	66	557
ADG, kg	13,266	1.56	0.353	0.10	3.70

**Table 2-2. Frequency of multiple gross pathology lesions observed at slaughter of 19,229 head of cattle from six U.S. High Plains feedyards**

Item	Level	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Lung <sup>1</sup>	Normal	12934	67.3	12934	67.3
	Mild	4335	22.5	17269	89.8
	Severe	1881	9.8	19150	99.6
	Unknown	79	0.4	19229	100.0
Liver <sup>2</sup>	Normal	13183	68.6	13183	68.6
	A-	1579	8.2	14762	76.8
	A	1495	7.8	16257	84.6
	A+	877	4.6	17134	89.1
	Fluke/Parasite	409	2.1	17543	91.3
	Misc.	1158	6.0	18701	97.3
	Telang.	192	1.0	18893	98.3
	Cirrhosis	28	0.2	18921	98.4
	Unknown	308	1.6	19229	100.0
Rumen <sup>3</sup>	Normal	9863	51.3	9863	51.3
	Mild	2610	13.6	12473	64.9
	Severe	2025	10.5	14498	75.4
	Unknown	4731	24.6	19229	100.0

<sup>1</sup>Gross lung pathology at slaughter: Normal: No visible gross pathological evidence of lesions associated with BRDC. Mild: < 50% consolidation of any single lung lobe with lesions associated with BRDC. Severe: >50% consolidation of any single lung lobe with lesions associated with BRDC or any sign of pleural adhesion to the thoracic cavity.

<sup>2</sup>Gross liver pathology at slaughter: Normal: livers free from abscesses, parasites, or other pathological abnormalities. A-: livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars. A: livers which displayed 2 to 4 abscesses 2 to 4 cm in diameter. A+: livers displaying  $\geq 1$  abscesses  $> 4$  cm in diameter or  $> 4$  abscesses  $> 2$ cm in diameter, adhesions to the body wall or other organs, or a ruptured abscess. Fluke/Parasite: livers displaying evidence of infestation by flukes (*Fasciola hepatica* or other). Misc.: Liver condemned for miscellaneous reason or contamination. Telang: livers displaying gross pathologic evidence of telangiectasis. Cirrhosis: livers displaying gross pathologic evidence of cirrhosis.

<sup>3</sup>Gross rumen pathology at slaughter: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae Thompson (1967).

**Table 2-3 Associative effects of lung, liver, and rumen gross pathology lesions observed at slaughter on average daily gain (kg) in feedlot cattle.**

Effect	Level	$\beta$	SE	Pr > t	Fixed Effect P	Tukey adj. P vs. Normal
Lung <sup>2</sup>	Normal	Ref <sup>1</sup>	-	-	<0.01	-
	Mild	0.01	0.006	0.02		< 0.01
	Severe	-0.07	0.008	< 0.01		< 0.01
Liver <sup>3</sup>	Normal <sup>1</sup>	Ref <sup>1</sup>	-	-	<0.01	-
	A-	0.01	0.009	0.51		0.55
	A	-0.02	0.009	0.06		0.28
	A+	-0.10	0.011	< 0.01		< 0.01
	Fluke/Parasite	-0.01	0.017	0.37		0.03
	Misc.	-0.05	0.012	< 0.01		< 0.01
	Telang.	-0.01	0.026	0.76		1
	Cirrhosis	-0.27	0.062	< 0.01		< 0.01
Rumen <sup>4</sup>	Normal	Ref <sup>1</sup>	-	-	<0.01	-
	Mild	0.00	0.008	0.89		0.19
	Severe	-0.03	0.009	< 0.01		< 0.01

<sup>1</sup>Referent category

<sup>2</sup>Gross lung pathology at slaughter: Normal: No visible gross pathological evidence of lesions associated with BRDC. Mild: < 50% consolidation of any single lung lobe with lesions associated with BRDC. Severe: >50% consolidation of any single lung lobe with lesions associated with BRDC or any sign of pleural adhesion to the thoracic cavity.

<sup>3</sup>Gross liver pathology at slaughter: Normal: livers free from abscesses, parasites, or other pathological abnormalities. A-: livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars. A: livers which displayed 2 to 4 abscesses 2 to 4 cm in diameter. A+: livers displaying  $\geq 1$  abscesses > 4 cm in diameter or > 4 abscesses > 2cm in diameter, adhesions to the body wall or other organs, or a ruptured abscess. Fluke/Parasite: livers displaying evidence of infestation by flukes (*Fasciola hepatica* or other). Misc.: Liver condemned for miscellaneous reason or contamination. Telang: livers displaying gross pathologic evidence of telangiectasis. Cirrhosis: livers displaying gross pathologic evidence of cirrhosis.

<sup>4</sup>Gross rumen pathology at slaughter: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae Thompson (1967).



**Table 2-4. Associative effects of lung, liver, and rumen gross pathology lesions observed at slaughter on hot carcass weight (kg) in feedlot cattle.**

Effect	Level	$\beta$	SE	Pr > t	Fixed Effect P	Tukey adj. P vs. Normal
Lung <sup>2</sup>	Normal	Ref <sup>1</sup>	-	-	<0.01	-
	Mild	1.1	0.55	0.04		<0.01
	Severe	-7.1	0.81	<.01		<0.01
Liver <sup>3</sup>	Normal	Ref <sup>1</sup>	-	-	<0.01	-
	A-	0.3	0.85	0.67		1
	A	-1.5	0.83	0.07		0.99
	A+	-10.9	1.08	<.01		<0.01
	Fluke/Parasite	-1.8	1.59	0.26		0.99
	Misc.	-4.9	1.14	<.01		0.03
	Telang.	-1.1	2.48	0.65		1
	Cirrhosis	-28.5	5.96	<.01		<0.01
Rumen <sup>4</sup>	Normal	Ref <sup>1</sup>	-	-	<0.01	-
	Mild	0.1	0.73	0.83		<0.01
	Severe	-2.2	0.88	0.01		<0.01

<sup>1</sup>Referent category

<sup>2</sup>Gross lung pathology at slaughter: Normal: No visible gross pathological evidence of lesions associated with BRDC. Mild: < 50% consolidation of any single lung lobe with lesions associated with BRDC. Severe: >50% consolidation of any single lung lobe with lesions associated with BRDC or any sign of pleural adhesion to the thoracic cavity.

<sup>3</sup>Gross liver pathology at slaughter: Normal: livers free from abscesses, parasites, or other pathological abnormalities. A-: livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars. A: livers which displayed 2 to 4 abscesses 2 to 4 cm in diameter. A+: livers displaying  $\geq 1$  abscesses > 4 cm in diameter or > 4 abscesses > 2cm in diameter, adhesions to the body wall or other organs, or a ruptured abscess. Fluke/Parasite: livers displaying evidence of infestation by flukes (*Fasciola hepatica* or other). Misc.: Liver condemned for miscellaneous reason or contamination. Telang: livers displaying gross pathologic evidence of telangiectasis. Cirrhosis: livers displaying gross pathologic evidence of cirrhosis.

<sup>4</sup>Gross rumen pathology at slaughter: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae Thompspon (1967).

**Table 2-5. Associative effects of lung, liver, and rumen gross pathology lesions observed at slaughter on the odds of grading Choice or better in yearling feedlot cattle.**

Effect	Level	Fixed Effect <i>P</i>	OR <sup>5</sup>	Lower	Upper	Tukey adj. <i>P</i> vs Normal
Lung <sup>2</sup>	Normal	0.99	Ref <sup>1</sup>	-	-	-
	Mild		1.00	0.915	1.097	0.76
	Severe		1.00	0.883	1.148	0.92
Liver <sup>3</sup>	Normal	0.32	Ref <sup>1</sup>	-	-	-
	A-		0.94	0.819	1.083	0.99
	A		0.91	0.8	1.052	1
	A+		0.94	0.796	1.130	0.65
	Fluke/Parasite		0.86	0.669	1.122	0.99
	Misc.		1.19	0.992	1.435	1
	Telang.		1.23	0.828	1.838	1
	Cirrhosis		0.65	0.256	1.655	0.71
Rumen <sup>4</sup>	Normal	0.17	Ref <sup>1</sup>	-	-	-
	Mild		1.11	0.987	1.250	0.98
	Severe		1.11	0.962	1.288	0.06

<sup>1</sup>Referent category

<sup>2</sup>Gross lung pathology at slaughter: Normal: No visible gross pathological evidence of lesions associated with BRDC. Mild: < 50% consolidation of any single lung lobe with lesions associated with BRDC. Severe: >50% consolidation of any single lung lobe with lesions associated with BRDC or any sign of pleural adhesion to the thoracic cavity.

<sup>3</sup>Gross liver pathology at slaughter: Normal: livers free from abscesses, parasites, or other pathological abnormalities. A-: livers which displayed ≤ 2 abscess ≤ 2 cm in diameter, or resolved abscess scars. A: livers which displayed 2 to 4 abscesses 2 to 4 cm in diameter. A+: livers displaying ≥ 1 abscesses > 4 cm in diameter or > 4 abscesses > 2cm in diameter, adhesions to the body wall or other organs, or a ruptured abscess. Fluke/Parasite: livers displaying evidence of infestation by flukes (*Fasciola hepatica* or other). Misc.: Liver condemned for miscellaneous reason or contamination. Telang: livers displaying gross pathologic evidence of telangiectasis. Cirrhosis: livers displaying gross pathologic evidence of cirrhosis.

<sup>4</sup>Gross rumen pathology at slaughter: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae Thompson (1967).

<sup>5</sup>Odds ratio of a carcass grading choice or better

# **Chapter 3 - A Survey of Gross Pathologic Conditions in Cull Cows at Slaughter in the Great Lakes region of the U.S. <sup>1</sup>**

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## Abstract

**Objective-** Evaluate the prevalence and severity of multiple gross pathologic lesions and abnormalities in cull dairy and beef cows at slaughter in the Great Lakes region of the U.S. .

**Methods-** At a commercial abattoir in the Great Lakes region of the United States, 1,481 cattle were examined at slaughter over the course of 3 production days and evaluated for the occurrence and severity of lung, liver, rumen, and carcass abnormalities and pathologies.

**Results-** Of the 1,461 cattle examined at slaughter, 87% were classified as Holsteins while 13% were classified as other cows. Liver abscesses were observed in 32 % of the population and over half were classified as severe (18.5% population prevalence). The distribution of cattle observed with a liver abscess was not different among production days ( $Pr > ChiSq = 0.86$ ). Severe ruminal lesions and rumenitis scars were observed in 10.0 % of the population and 25.1% of cattle were observed with short or denuded papillae. Severe bovine respiratory disease complex lesions were observed in 10.3 % of cattle. The most common reason for USDA postmortem carcass condemnation was malignant lymphoma (9/41). Only 45.9% of carcasses were free from bruising.

**Conclusion-** Results suggest that ruminal acidosis and bovine respiratory disease complex occur with a relatively high frequency in this population. Though cows are routinely culled for reproduction or milk production, the underlying reason may be casually related to these conditions. Further investigation is needed to assess this relationship and to examine the use of specific health intervention strategies within this demographic of cattle.

## Introduction

The culling of dairy or beef cattle from their respective herds is an unavoidable, necessary, and humane practice that ensures animals are not kept past their productive and healthy lifespan. In order to ensure a safe and wholesome food supply, this practice must be carried out in a timely and effective manner that does not allow animals to reach a point of poor and non-transportable condition. The sale of cows which are no longer able to effectively conceive, carry, and wean a calf or produce milk contributes significantly to the beef supply; In 2012, 19.9% of the total number of federally inspected slaughter cattle in the U.S. were characterized as cows (9.6% dairy cows, 10.3% other cows) by the USDA FSIS <sup>[1]</sup>. Moreover, the sale of cull animals by producers contributes from 4-20% of operational gross revenue for beef and dairy operations<sup>[2]</sup> in addition to the economic benefit of the removal/replacement of an animal who may no longer be capable of profitability and, given the steady decline of the U.S. cattle inventory<sup>[3]</sup> the value of these animals for all purposes is likely to increase. Additionally, public concerns and attitudes regarding the care and health of animals entering the food chain are an increasingly important factor for consideration; therefore it is necessary to correctly identify opportunities to increase the plane of animal well-being at every juncture in the food supply chain including production, culling and harvest. Moreover, collecting and monitoring objective data that are correlated with common production-related diseases and practices provide useful information to many parties. Culling is often carried out in a non-programmed and relatively subjective manor<sup>[4]</sup>; however, it is important to correctly identify the causative factors that contribute to cows leaving the herd. It is only then that specific and judicious interventions can be introduced into a production system

to effectively improve the health, well-being, and long term profitability of cows in dairy or beef operations. McConnel et al.<sup>[5]</sup> recognized this shortcoming in most dairy operations and proposed that necropsies be performed to aid in identifying causative factors in mortalities on dairy farms. Moreover, it was observed that producers only correctly identified the cause of mortalities in 55% of the cases, and if traumatic accidents and locomotor disorders were removed from the data set, 41% of mortality cases.

While on farm mortality is certainly a critical dynamic to understand within a herd in order to develop appropriate intervention strategies, equally as important to the herd health and welfare are the factors that may have led to culling. Multiple reports have outlined gross trends in reasons for culling in U.S. and Canadian dairy herds<sup>[6-9]</sup> however, information relating to beef cattle herds specifically is lacking but a single report does cite old age/bad teeth as a primary reason<sup>[10]</sup>.

Ruminal acidosis affects both fed beef cattle and dairy cows. However, accurate diagnosis of ruminal acidosis, either clinical or subacute ruminal acidosis (SARA) is challenging. Common consequences of ruminal acidosis in dairy cows are decreased dry matter intake, milk fat depression, reduced fiber digestion, loss of body condition, diarrhea, laminitis, rumenitis, liver abscesses and culling<sup>[11,12]</sup>. Studies have attempted to estimate the occurrence of SARA in herds utilizing pH measurements of ruminal fluid collected via rumenocentesis along with a structured sampling procedure<sup>[13]</sup> and have reported prevalence's ranging from 19-40%<sup>[14]</sup>; however such monitoring is not common practice within the industry. In fed beef cattle, liver abscesses, a sequela to ruminal acidosis, are commonly diagnosed at slaughter<sup>[15]</sup>. This objective data can then be used to gauge nutritional, health and managerial practices or used as an aid to drive intervention strategies. The opportunity exists at the time of culling to collect similar data on

cows. Examination of the interior of the rumen at the time of slaughter may also be a valuable diagnostic tool for nutritional health<sup>[16]</sup>. Hepatic abscesses have been shown to be resolved into scars within 50 to 70 days after portal inoculation with *Fusobacterium necrophorum*<sup>[17]</sup>. However, once the rumen epithelium is compromised and morphologic changes occur, the absorptive capacity of the affected tissue is lost, which may further exacerbate the accumulation of volatile fatty acids and/ or lactic acid<sup>[11]</sup>. Therefore, monitoring both the rumen and the liver for lesions and abscesses may provide a more complete diagnostic tool for ruminal acidosis than liver abscesses alone.

Bovine respiratory disease complex (BRDC), though normally approached as a problem limited to younger cattle<sup>[18]</sup> exposed to risk factors and stressors such as weaning, transportation, and comingling<sup>[19]</sup> also affects aged cows. Data suggests that pneumonia is the second leading cause of postmortem carcass condemnations in dairy cows<sup>[20]</sup> and also a leading proximate cause of death in postmortem examinations of dairy cattle<sup>[5]</sup>. The sensitivity and specificity of traditional diagnosis of BRDC in fed beef cattle using clinical scoring alone has been estimated to be 61.8% and 62.8%, respectively, however, utilizing lung lesions at harvest for BRDC diagnosis improves sensitivity and specificity to 77.4% and 89.7%, respectively<sup>[21]</sup>. Therefore, monitoring lungs at slaughter in cull cows for signs of pulmonary lesions may also yield valuable information to veterinarians and other herd health personnel that control management and health intervention strategies.

Though not a production related disease, bruising of cattle as a result of handling and transportation to harvest facilities is important to minimize for both welfare and economic reasons. Rosse (1974)<sup>[22]</sup> estimated quantitative economic losses attributed to carcass bruises at

\$22.4 million, however this figure likely needs to be revisited due to the stark changes in production, transportation, and management since the 1970's. Nevertheless, bruising is also an indication of compromised welfare <sup>[23]</sup> and should be included as an objective measurement in a comprehensive program.

The objective of this study was to investigate the prevalence of multiple gross pathologies at slaughter in cull cattle at a commercial abattoir in the Great Lakes region of the U.S. in order to provide data regarding the prevalence of important production related diseases and defects in cull cattle.

## **Materials and Methods**

Animal care and use committee approval was not received for the methods used in this study as no live animals were utilized.

Cattle were enrolled into the study via communication between the cooperating abattoir and Kansas State University. A total of 1,461 cattle were examined at slaughter over the course of 3 production days from 28May2013-30May2013 and evaluated for the occurrence and severity of multiple gross pathology lesions and abnormalities.

Teams of trained investigators comprised of undergraduate, graduate, and veterinary students were dispatched to a single commercial abattoir to gather gross pathology data. Prior to gathering data, all personnel were trained utilizing a combination of self-study and instructor-led training material on all data collection procedures and for the entirety of the data collection, a homogenous crew of personnel was utilized and each crew member's respective assignment for the entirety of the data collection process.



Lung scores were assigned by visually evaluating lungs as they passed by a single investigator stationed along the offal table. Lungs were scored on a 3-point scale as follows similar to that of Thompspon et al. (2006) <sup>[24]</sup> Normal: No visible gross pathological evidence of lesions associated with BRDC. Mild: < 50% consolidation of any single lung lobe with lesions associated with BRDC. Severe: >50% consolidation of any single lung lobe with lesions associated with BRDC or any sign of pleural adhesion to the thoracic cavity. Although lesions occurring in any portion of the lung were noted and assigned a score, personnel were instructed in training materials to make a careful diagnosis of the right cranial and middle lobes as a previous investigation has shown that > 86% of lesions are detected when only evaluating those anatomical locations <sup>[25]</sup>. Livers were evaluated for the presence of abnormalities by a single investigator stationed along the offal table. Hepatic abscesses were scored using a modified Elanco Liver Check System (Elanco, Greenfield, IN). Livers that were deemed free from abscesses, parasites, or other pathological abnormalities were classified as Normal. An A- was assigned to livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars, an A designation was assigned to liver displaying 2-4 abscesses 2-4 cm in diameter, an A+ was assigned to livers displaying  $\geq 1$  abscesses > 4 cm in diameter or > 4 abscesses > 2cm in diameter. Abscesses adhered to the diaphragm, other organs or the abdominal cavity were noted and classified as A+A. Likewise, abscesses that were ruptured or “open” leading to the condemnation of all offal for the respective carcass were scored as an A+O. Livers with adhesions and ruptured abscesses were denoted as an A+AO. For the purposes of this report however, A+A, A+O, and A+AO scores were consolidated into the A+ category for prevalence and performance association data. The occurrence of other abnormalities including, liver flukes and other parasites, telangiectasis

(of all degrees), hepatic lipidosis (fatty liver) and cirrhosis as well as livers condemned due to contamination or miscellaneous criteria were recorded.

The ruminal mucosa was evaluated for the presence of gross pathological lesions associated with ruminal acidosis. Following evisceration, each rumen was drained of digesta and hung on the processing chain as per normal plant procedures. Gross pathological diagnosis was accomplished in teams of two; one crew member palpated and manipulated the rumen to allow for thorough inspection of the lumen and verbally dictated a score to a recorder. Scores were assigned according to the following system: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae <sup>[26]</sup>. Rumens condemned by USDA inspection were not assigned a score or included in the prevalence data.

Carcass bruises were assessed by a single investigator stationed along the production line after the hide was removed and before the carcass was split. The location of the bruise was noted according to a predetermined grid with 9 (3x3) possibilities and number assigned according to denote the location of the bruise given the following anatomical borders and landmarks for the respective numbers. 1: Right hind limb - cranial border is a transverse line at the level of the lumbosacral junction and extends caudally including the distal right hind limb. The medial border of this region bisects the round on the right hindquarter. 2: Midline tailhead – cranial border beginning at the lumbosacral junction and extending caudally. Lateral borders bisect the

left and right rounds. 3: Left hind limb - cranial border is a transverse line at the level of the lumbosacral junction and extends caudally including the distal left limb. The medial border of this region bisects the round on the left hindquarter. 4: Right barrel – cranial border is a transverse line at the level of the 7<sup>th</sup> thoracic vertebrae extending caudally to a transverse line at the lumbosacral junction. The medial border of this region is the lateral border of the right epaxial muscles. 5: Midline barrel – cranial border beginning at the 7<sup>th</sup> thoracic vertebrae extending caudally to the lumbosacral junction. 6: Left barrel - cranial border is a transverse line at the level of the 7<sup>th</sup> thoracic vertebrae extending caudally to a transverse line at the lumbosacral junction. The medial border of this region is the lateral border of the left epaxial muscles. 7: Right forelimb – caudal border is a transverse line at the 6<sup>th</sup> thoracic vertebrae extending cranially including the distal right forelimb. The medial border of this region bisects the chuck on the right side. 8: Midline shoulder – caudal border is at the level of the 6<sup>th</sup> thoracic vertebrae and extends cranially. Lateral borders of this region bisect the left and right chuck. 9: Left Forelimb - caudal border is a transverse line at the 6<sup>th</sup> thoracic vertebrae extending cranially including the distal left forelimb. The medial border of this region bisects the chuck on the left side. For the purposes of this report, grid location numbers were transcribed in gross anatomical areas of interest (e.g. the hip, back, etc.). In addition to the location of each bruise, one of three severity scores was assigned as follows: Mild: < 3 inches<sup>2</sup> of affected surface area, Moderate: 3-28 inches<sup>2</sup> of affected surface area or Severe: > 28 inches<sup>2</sup> of affected surface area.

A calculation to determine the sample size needed for surveying the frequency of severe BRDC lung lesions in a population was completed *a priori* according to Schaffer et al. (1990) <sup>[27]</sup> using the following inputs: Population size: 6.5 million, anticipated percent frequency of event: 10%,

Confidence limits ( $\pm$ ): 5%, and a design effect adjustment factor of 10 to account for cluster sampling. As a result, a total of 1,383 (95% confidence level) cattle were determined to be needed. Following collection, data were entered into, stored and managed using a computer based database program (Microsoft Excel for Windows 2010). Frequency distributions were calculated utilizing a computer based statistical analysis software and frequency differences utilizing the Chi-squared test in Proc Freq of SAS (SAS Version 9.3, Cary, NC). Significance was declared at  $P \leq 0.05$ .

## Results

Of the 1,461 cattle examined at slaughter, 87% were classified as Holsteins, presumably all from dairy operations, while 13% were classified as other cows. Thirty-five percent of the total study population was observed on day 1, 45% on day 2, and 20% on day 3. On day 1, 92% of the population was classified as Holsteins followed by 79% and 94% on days 2 and 3 of data collection, respectively.

Thirty-two percent of cattle were observed with a liver abscess of varying severity at slaughter and over half (18.5 %) were severe in nature (Table 1.) The distribution of cattle observed with a liver abscess was not different among production days ( $Pr > ChiSq = 0.86$ ). A vast majority of the severe abscesses (90%) were observed with at least one abscess adhered to the diaphragm, body wall, or other organ. Relatively few cattle were observed with more than 1 gross pathological abnormality (3 head total) however, animals with more severe conditions such as A+ abscess with an adhesion may have masked other less pronounced gross lesions.

Rumen health scores can be seen in Table 2. Overall, 35 % of the population was observed with some kind of rumen epithelium abnormality. The distribution of cattle observed with a rumen

epithelium abnormality was different among production days ( $P > \text{ChiSq} < 0.01$ ) and was 25.7, 39.1, and 47.62% for day 1, 2, and 3, respectively. The most prevalent abnormality was denuded, sparse, or short papillae (25.1%). Lesions were found almost invariably on the luminal ventral surface of the ventral sac as well as the luminal ventral surface of the caudodorsal blind sac.

Pulmonary lesions associated with BRDC were observed in 33.8% of all cattle (Table 3). Mild lesions ( $\leq 50\%$  consolidation of any lung lobe) were the most common and were found in 23.5% of cattle. The distribution of cattle with a BRDC lesion was not different among production days ( $P > \text{ChiSq} = 0.59$ ). The odds of a lung lesion given the presence of a liver abscess were not significantly different than the odds given of a lung lesion when no abscess was present (Odds ratio 1.09, 95% Confidence Limit: 0.86 – 1.37,  $P=0.48$ ) and 33.4% of cattle with a liver abscess also had a BRDC lung lesion whereas 68.5% of cattle that did not have a lung lesion did not have a liver abscess.

The frequency of carcasses condemned due to USDA postmortem inspection was also determined. Overall, 2.8% of the population (41 animals) was condemned due to USDA FSIS veterinary medical officer postmortem inspection. The specific diagnosis (reason for condemnation) can be seen in Table 4. The most frequent reasons for postmortem condemnation were malignant lymphoma (9/41), abscess/pyemia (8/41), and septicemia (8/41).

Some degree of bruising was observed on 54.1 % of carcasses. Bruises were observed on the hip region of 36.5 % of carcasses and on the back of 24.3 % of carcasses. Overall, 11.6 % of carcasses were affected by at least one severe bruise ( $> 28 \text{ inches}^2$  of affected surface area). The frequency distribution of carcasses with a bruise was significantly different by production day ( $P > \text{ChiSq} < 0.01$ ) and was 43.6, 54.5, and 70.3% for days 1, 2, and 3 respectively.

Furthermore, a carcass was more likely to have a back bruise given a hip bruise was also present

(Odds ratio 2.2, 95% Confidence Limit: 1.75 – 2.84,  $P=0.01$ ) and 33.9 % of cattle with a hip bruise also had a back bruise whereas 81.3% of cattle that did not have a hip did not have a back bruise. Frequency and percent prevalence of number of bruises observed on each carcass can be seen in Table 5.

## Discussion

In 2012, dairy cows accounted for approximately 48% of all federally inspected cows slaughtered (9.6% of the total head slaughtered) in the U.S. <sup>[1]</sup>. Therefore it should be noted that the population investigated here does not represent the demographics of the U.S. as a whole, but does focus on cull cows originating from dairies, specifically. Published peer reviewed data concerning the prevalence and severity of gross lesions in cull cattle at slaughter is limited. Ahola et al. (2011) completed a comprehensive survey of various quality defects in beef and dairy cows and bulls sold through livestock auction markets in the western U.S., however, only exterior defects and lesions were noted. Furthermore, the National Beef Quality Audit (NBQA), which does report data on liver condemnations, lung lesions, and carcass bruising, does not include data from cull cows <sup>[28]</sup>.

Dairy cows, specifically, are at risk for developing ruminal acidosis due to the rapid and marked change in diet (from low to high nonstructural carbohydrate) when transitioning through the various stages of the production period (i.e. gestating to lactating). Liver abscesses are common sequelae to cases of ruminal acidosis where the rumen epithelium is damaged by a high concentration of organic acids (and low pH). The 32.2% liver abscess prevalence reported here is a 570% increase over that reported by the most recent NBQA in fed cattle (4.8%, 2011) <sup>[28]</sup> and a 128% increase compared to the prevalence reported by the 2007 National Market Cow and

Bull Beef Quality Audit (14%)<sup>[29]</sup> There are likely many explanations for this finding. Perhaps the leading factor is the lack of perception of the problem within the veterinary and animal health community. As aforementioned, little published data exists on the prevalence and severity of liver abscesses in cull cows though proposals to do so have been made<sup>[30]</sup>. One published report does document liver abscesses in dairy cows at a veterinary teaching hospital over the course of nearly 12 years, however, those data were derived from individual case reports as opposed to a large cross sectional study that is more likely to represent the true prevalence in the population<sup>[31]</sup>. Another likely cause for the high prevalence observed is the lack of specific interventions available for use in lactating dairy cows; antimicrobial feed additives such as tylosin, the most common intervention for liver abscesses in feedlot cattle<sup>[15]</sup>, are labeled only for use in beef cattle, therefore cows culled and directly sent to slaughter from the herd are never able to receive the treatment. Liver abscesses in cows can also be the result of traumatic reticuloperitonitis<sup>[30]</sup> (“Hardware disease”). The etiopathogenesis for this condition involves puncture of the reticular wall by an ingested foreign body, usually metallic, and subsequent peritonitis, pericarditis, myocarditis, endocarditis, pleuritis, pneumonitis, liver abscess, or septicemia depending on the extent of trauma inflicted by the foreign body<sup>[32]</sup>. Since several of the carcasses condemned by postmortem USDA inspection were diagnosed with the above pathologies, it is likely that a number of these animals suffered from hardware disease.

The rumen is the primary foci of infection in the rumenitis-liver abscess complex<sup>[33]</sup>. As aforementioned, during a case of acidosis, the rumen epithelium may become damaged by the low pH. Clumping and irregular growth patterns in the ruminal papillae may indicate some damage to the epithelium; however, common gross results of subacute or clinical acidosis include parakeratosis, blunted or denuded areas of papillae, and in more severe cases, ulceration

of the epithelium and subsequent rumenitis lesions. The damaged and now vulnerable ruminal wall is then subject to colonization by normally commensal microorganisms of the rumen including fungi and bacteria. The primary pathogen of interest however is the gram negative anaerobe *Fusobacterium necrophorum*, which can form abscesses in the ruminal wall or emboli which are trans-located to the liver via portal circulation where they ultimately form an abscess as a result of the multifaceted set of virulence factors possessed by *Fusobacterium necrophorum*<sup>[34]</sup>. Given the high prevalence of liver abscesses in this population of cattle, a corresponding high prevalence of abnormal rumen health scores (mild, severe, and scars) should come as no surprise. Unfortunately, statistical correlation of individual rumen score with liver score was not plausible due to challenges presented by processing practices at the abattoir. The chronic form of the majority of the ruminal pathology (scars and consolidated expanses of denuded papillae) may suggest a long term exposure of the ruminal epithelium to an unfavorable environment.

Similar to liver and rumen pathology data, information in the published literature relating to BRDC in cull cows at slaughter is lacking. Traditionally, intervention efforts for respiratory disease in cattle are focused on young, growing stock<sup>[18]</sup>. However, the lung lesion prevalence rates observed in the current study suggest that more attention to diagnosis and treatment may be required. Supporting this idea are the data from a necropsy-based longitudinal study of an individual U.S. dairy which observed that pneumonia (chronic & acute) was a leading cause of proximate death on the farm<sup>[5]</sup>. A shortcoming commonly called to question when discussing pulmonary lesions as a diagnostic indicator for BRDC is the age of the lesion itself (ie. when did the disease occur?). Although aging of lesions is difficult, it can be concluded that the presence



of a consolidated lesion likely indicates a case of lobar bronchopneumonia where irreversible structural change has taken place at some time point in the animal's life <sup>[35]</sup>.

The overall bruising prevalence of 54.1 % observed here is numerically less than that observed by the 2007 National Market Cow and Bull Beef Quality Audit (63.4%). However, both were over twice the prevalence reported by the most recent NBQA in fed beef cattle (23%) <sup>[28]</sup>. There are numerous sources of variation that contribute to the prevalence and severity of carcass bruises. Jarvis et al. <sup>[23]</sup> examined the influence of source, sex class, and handling on bruising in cattle from two UK slaughterhouses. Overall prevalence of bruising was remarkably high (97%) and cattle sourced from auction markets had a significant higher median number of bruises per carcass than did cattle sourced directly from farms. Slaughter lots of heifers, and bulls had the least amount of bruising at slaughter compared to lots of steers or mixed steers and heifers within a common source. Similar sex classification influence was observed by Weeks et al. <sup>[36]</sup> and the authors hypothesized this was likely due to a number of factors including hide thickness, fat depth, temperament, and response to stimuli. Significant correlation was found between the use of driving aids and the occurrence of bruising of multiple areas of the carcass. In the U.S., Hoffman et. al <sup>[37]</sup> examined the associations of carcass bruising with transportation distance to slaughter and concluded that the carcasses of mature beef cows marketed through livestock auctions that conducted first-point testing for brucellosis were observed with a greater number and severity of bruises that their cohorts sourced from ranches or auction markets not conducting first –point testing, this increase was exacerbated when cows were transported >325km. The authors concluded that the repeated handling and restraint of the first-point tested cows resulted in the increased prevalence and severity of bruising. In the current study, the majority of cattle

were transported in double decker aluminum “cattle pots” which are typical for mass transportation of cattle in the U.S. and it was observed that many Holstein cows were too tall to negotiate several of the points within the trailers without striking either their hip or back, which coincides with the high prevalence of bruises in both of the respective areas. Hence, the design of high capacity trailers for primary use by transportation entities that typically move cull cows to and from market may warrant further investigation.

The high prevalence of lesions indicative of BRDC and ruminal acidosis suggests that significant levels of these diseases exist within the production population. Additional investigation is warranted in order to correlate lesions at slaughter with the reason individual cows were selected to be removed from their herd as well as collect information from other geographic locations and time points. Furthermore, the high prevalence of liver abscesses suggests that significant opportunity exists for application of specific interventions such as vaccines which are designed to stimulate immune response to *Fusobacterium necrophorum*. However, microbiological examination of liver abscesses should be carried out to identify the pathogens implicated in these instances. Given the high profile nature and public perception often associated with this important and necessary sector of the industry, it would behoove all parties involved to invest additional time and resources to ensure the highest plane of health and well-being of cull cows and identify and address areas of opportunity.

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**Table 3-1. Frequency and percent prevalence of hepatic abscesses and abnormalities in cull cows at slaughter in the Great Lakes region of the U.S.**

<b>Liver Score<sup>1</sup></b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
<b>Normal</b>	656	44.9	656	44.9
<b>A-</b>	103	7.1	759	52.0
<b>A</b>	95	6.5	854	58.5
<b>A+</b>	271	18.6	1,125	77.0
<b>A &amp; Parasite</b>	1	0.1	1,126	77.1
<b>Fatty Liver</b>	46	3.2	1,172	80.2
<b>Fatty Liver &amp; Parasite</b>	2	0.1	1,174	80.4
<b>Parasite</b>	90	6.2	1,264	86.5
<b>Telang.</b>	15	1.0	1,279	87.6
<b>Contamination</b>	105	7.2	1,384	94.7
<b>Cirrhosis</b>	2	0.1	1,386	94.9
<b>Unknown</b>	28	1.9	1,414	96.8
<b>Misc.</b>	47	3.2	1,461	100.0

<sup>1</sup>Gross liver pathology at slaughter: Normal: livers free from abscesses, parasites, or other pathological abnormalities. A-: livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars. A: livers which displayed 2 to 4 abscesses 2 to 4 cm in diameter. A+: livers displaying  $\geq 1$  abscesses  $> 4$  cm in diameter or  $> 4$  abscesses  $> 2$ cm in diameter, adhesions to the body wall or other organs, or a ruptured abscess. Fatty Liver: Liver displaying gross evidence of hepatic lipidosis. Telang.: livers displaying gross pathologic evidence of telangiectasia. Parasite: livers displaying evidence of infestation by flukes (*Fascioloides magna* or other). . Contamination: Liver condemned for contamination (hair, digesta, etc.) Cirrhosis: livers displaying gross pathologic evidence of cirrhosis. Unknown: Diagnosis of the liver was not carried out. Misc.: Liver condemned for miscellaneous reasons.

**Table 3-2. Frequency and percent prevalence of rumen epithelial health scores in cull cattle at slaughter in the Great Lakes region of the U.S. (n=1,048).**

<b>Rumen Score<sup>1</sup></b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative</b>	<b>Cumulative</b>
			<b>Frequency</b>	<b>Percent</b>
<b>Normal</b>	679	64.8	679	64.8
<b>Mild</b>	263	25.1	942	89.9
<b>Severe</b>	30	2.9	972	92.8
<b>Scar</b>	74	7.1	1,046	99.8
<b>Unknown</b>	2	0.2	1,048	100.0

<sup>1</sup>Gross rumen pathology at slaughter: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci. Scar: healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae <sup>[15]</sup> Unknown: Diagnosis of the rumen was not carried out.

**Table 3-3 Frequency and percent prevalence of bovine respiratory disease complex (BRDC) associated lesions in cull cattle at slaughter in the Great Lakes region of the U.S.**

<b>Lung Score<sup>1</sup></b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
<b>Normal</b>	949	65.0	949	65.0
<b>Mild</b>	343	23.5	1,292	88.4
<b>Severe</b>	151	10.3	1,443	98.8
<b>Unknown</b>	18	1.2	1,461	100.0

<sup>1</sup>Gross lung pathology at slaughter: Normal: No visible gross pathological evidence of lesions associated with BRDC. Mild: < 50% consolidation of any single lung lobe with lesions associated with BRDC. Severe: >50% consolidation of any single lung lobe with lesions associated with BRDC or any sign of pleural adhesion to the thoracic cavity. Unknown: Diagnosis of the lungs was not carried out.

**Table 3-4. Frequency and percent prevalence of USDA diagnosis and reason for postmortem carcass condemnation in 41 cull cows at slaughter in the Great Lakes region of the U.S.**

<b>USDA Diagnosis</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
<b>Abscess/Pyemia</b>	8	19.5	8	19.5
<b>Carcinoma</b>	2	4.9	10	24.4
<b>Icterus</b>	2	4.9	12	29.3
<b>MD &amp; DC</b>	2	4.9	14	34.1
<b>Malignant Lymphoma</b>	9	22.0	23	56.1
<b>Pericarditis</b>	4	9.8	27	65.9
<b>Peritonitis</b>	4	9.8	31	75.6
<b>Pneumonia</b>	2	4.9	33	80.5
<b>Septicemia</b>	8	19.5	41	100.0

<sup>1</sup>Reason provided for postmortem USDA FSIS carcass condemnation. MD & DC = Miscellaneous Degeneration and Dropsic Condition

**Table 3-5. Frequency and percent prevalence of the number of bruises observed on the carcasses of cull cows at slaughter in the Great Lakes region of the U.S. (n=1,461).**

<b>No. Bruise<sup>1</sup></b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
<b>0</b>	671	45.9	671	45.9
<b>1</b>	343	23.5	1014	69.4
<b>2</b>	265	18.1	1279	87.5
<b>3+</b>	182	12.5	1461	100.0

<sup>1</sup>Number of bruises observed on a carcass.



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**Chapter 4 - Performance and health of yearling feeder cattle dosed with a commercially available *Megasphaera elsdenii* direct fed microbial on arrival.<sup>1</sup>**

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## Abstract

Cattle not previously exposed to high concentrate rations are a greater risk for developing clinical or subacute ruminal acidosis due to their naive rumen microbial population. A commercially available strain of the lactate utilizing bacteria *Megasphaera elsdenii* (NCMIB 41125) has been shown to be efficacious as a ruminal fermentation modifier. Therefore, the objective of this study was to evaluate the effects of orally dosing crossbred yearling steers with *Megasphaera elsdenii* (NCMIB 41125) in a commercial feeding facility utilizing practices in step with current U.S. industry standards. Yearling crossbred feeder steers (4,863 hd; 821 ±65.5 lbs.) were assembled from Southeast Colorado and the Southeast United States. Cattle were blocked by arrival lot and randomly assigned within block to one of two treatments: **Con:** no oral dose of *Megasphaera elsdenii* culture or **M.e.:** a 100 ml oral dose with the commercially available, proprietary strain of *Megasphaera elsdenii* (NCIMB 41125, 10<sup>9</sup> CFU/ml). Cattle were randomly allocated to treatment group in a 2:1 ratio method such that the total *n* for M.e. (*n*=3,242) was twice that of Con (*n*=1,621). No significant effects of treatment were detected for initial live weight (832 vs. 820 lbs.; *P*=0.83), final live weight (1,322 vs. 1,326; *P*=0.79) or hot carcass weight (851 vs. 853 lbs. *P*=0.81) for Con and M.e., respectively. Fourteen point two percent and 14.0% of Con and M.e., respectively displayed a liver abscess of varying severity at the time of slaughter. The ordinal odds ratio of a M.e. treated animal having a more severe liver abscess score was not significant (Estimate: 0.96, 95% C.L. 0.733-1.259, *P*=0.771). Overall, 8.27 and 7.96% % of Con and M.e. cattle were observed with an altered rumen epithelial health status. The ordinal odds ratio of a M.e. treated animal having a more severe rumen health score was not significant (Estimate: 1.01, 95% C.L. 0.625-1.63 *P*=0.96). These data indicate that

utilizing an oral drench of the commercially available strain of *Megasphaera elsdenii* (NCMIB 41125) at processing to alter the ruminal microbial population in yearling crossbred steers does not significantly alter carcass performance characteristics or gross pathological indices of ruminal health.



## Introduction

Usage and availability of direct fed microbial and probiotic feed additives and an animal supplement is increasing within the fed beef cattle industry. However, few large pen studies are published in peer reviewed literature for producers and consultants to confirm their efficacy or applicability to a commercial feeding program. Recently, delivering live cultures of the commercially available lactate utilizing bacteria, *Megasphaera elsdenii* (NCIMB 41125) as an oral drench prior to starting cattle has been suggested to attenuate complications and improve performance during the step up period<sup>6,9</sup>. Introducing a supplemental population of *Megasphaera elsdenii* to the rumen during this time period is theorized to decrease the quantity of the strong acid, lactate, in the rumen; therefore decreasing the likelihood of subacute ruminal acidosis (SARA) or acute ruminal acidosis.

In the case of SARA (ruminal pH 5.0-5.6), the decreased ruminal pH results mainly from an increase in the total concentration of total short chain fatty acids<sup>8</sup>, not an increased concentration of lactate. Therefore, labeling SARA as lactic acidosis is not correct. While the strong acid lactate is produced during subacute ruminal acidosis, lactate is simultaneously metabolized by lactate-fermenting bacteria<sup>5</sup> therefore pH is not maintained below 5.0 for an extended period of time as is found in acute acidosis. *Megasphaera elsdenii*, a gram-negative large coccus, is the predominant lactate fermenter (60-95% of the total) in the rumen<sup>2</sup> and is responsible for the majority of the microbial lactate utilization during SARA cases.

Ruminal acidosis, either acute or subacute can be difficult to diagnose. Variation in dry matter intake and feeding behavior may be a good indicator of rumen health<sup>1</sup> but is challenging to

objectively quantify on an individual basis in a feedyard setting and may be confounded by many other animal and environmental factors. However, observation of gross pathology at slaughter provides an objective evaluation technique that can be applied at an individual level with relative ease and accuracy. The two primary lesions of interest when investigating rumen health are liver abscesses and rumenitis lesions (Nagaraja and Chengappa, 1998). Quantifying these lesions in conjunction with analyzing performance data provides a more complete representation of the total impact feeding practices or interventions may have on rumen health.

The objectives of this investigation were to evaluate oral drenching cattle on arrival with a commercially available proprietary strain of *Megasphaera elsdenii* for its effect on carcass characteristics, and gross pathologic diagnostic indicators of ruminal acidosis in yearling feeder cattle in a U.S. commercial feedlot setting.

## **Materials and Methods**

### ***General***

The performance and health effects of dosing cattle on arrival with a commercially available, proprietary strain of *Megasphaera elsdenii* (NCIMB 41125, Lactipro, MS Biotec; Wamego, KS) were evaluated in 4,863 (821 ±65.5 lbs.) yearling crossbred feeder steers assembled from Southeast Colorado and the Southeast United States. Over a 30 day period, loads of cattle were received into a commercial feeding facility in the panhandle of Texas and rested for 8 hours before being subjected to a common receiving protocol. Cattle were blocked by arrival lot and

randomly assigned within block via random number generation to one of two treatments: **M.e.:** a 100ml oral dose with the commercially available, proprietary strain of *Megasphaera elsdenii* (NCIMB 41125,  $10^9$  CFU/ml) probiotic or **Con:** no oral dose of *Megasphaera elsdenii* culture. Cattle were randomly allocated to treatment group in a 2:1 ratio method such that the total  $n$  for M.e. ( $n= 3,242$ ) was twice that of Con ( $n=1,621$ ).

All cattle were treated with an anthelmintic, a multivalent respiratory vaccine, and given a steroid implant. Cattle were fed receiving and finishing rations in concordance to the standard operating procedures and protocols of the cooperating commercial feedyard; all rations were formulated to meet NRC requirements<sup>13</sup>. Following processing and random treatment allocation, cattle were assigned by treatment, within block to 48, 100 head dirt floor cattle feeding pens (Con = 16 pens, M.e. = 32 pens). All cattle were fed for a similar number of days and received a  $\beta$ -Agonist (Ractopamine Hydrochloride, Optaflexx; Elanco, Indianapolis, IN) for the final 28 days on feed. Cattle were shipped to two different commercial abattoirs for slaughter ; one in the panhandle of Texas and one the southwestern Kansas, where a team of investigators from Kansas State University collected individual gross pathology data.

The teams of investigators were comprised of undergraduate, graduate, and veterinary students. Prior to gathering data, all personnel were trained utilizing a combination of self-study and instructor-led training material on all data collection procedures, however, attempts were made to utilize a homogenous crew of personnel as well as to maintain each crew member's respective assignment for the entirety of the data collection process

Loin area and 12<sup>th</sup> rib fat thickness were measured and calculated by video image analysis.

Quality grade was assigned by USDA AMS Meat Grading and Certification Branch personnel.

Individual carcass, adjusted final live weight, was calculated by dividing individual hot carcass weight by dressing percent.

Livers were evaluated for the presence of abnormalities by a single investigator stationed along the offal table and scored using a modified Elanco Liver Check System (Elanco, Greenfield, IN). Livers that were deemed free from abscesses, parasites, or other pathological abnormalities were classified as Normal. An A- was assigned to livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars, an A designation was assigned to liver displaying 2-4 abscesses 2-4 cm in diameter, an A+ was assigned to livers displaying  $\geq 1$  abscesses  $> 4$  cm in diameter or  $> 4$  abscesses  $> 2$ cm in diameter. Abscesses adhered to the diaphragm, other organs or the abdominal cavity were noted and classified as A+A. Likewise, abscesses that were ruptured or “open” leading to the condemnation of all offal for the respective carcass were scored as an A+O. Livers with adhesions and ruptured abscesses were denoted as an A+AO. For the purposes of this report however, A+A, A+O, and A+AO scores were consolidated into the A+ category for prevalence and performance association data. The occurrence of other abnormalities including, liver flukes and other parasites, telangiectasis (of all degrees), and cirrhosis as well as livers condemned due to contamination or miscellaneous criteria were recorded.

The ruminal mucosa was evaluated for the presence of gross pathological lesions associated with the ruminal acidosis. Each rumen was identified with the respective carcass number of the animal from which it originated. Following evisceration, each rumen was drained of digesta and hung on the processing chain as per normal plant procedures. The area of the plant that was designated for ruminal scoring to take place varied by plant location. Visual gross pathological

diagnosis was accomplished in teams of 3; 1 crew member noted the plant carcass number and placed a tag on the esophagus. At the data collection area, 1 crew member read the identification number and communicated it to the crew member assigning lesion scores. Scores were assigned according to the following system: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae<sup>17</sup>. Rumens condemned by USDA inspection were not assigned a score. Likewise, if proper identification of the rumen was not accomplished, individual data were not retained and a designation of unknown was entered in the animal's record.

### ***Statistical Analysis & Data Management***

Data were stored and managed using Microsoft Excel for Windows 2010. Prior to analysis, a list of complete animal records were randomly selected to cross reference with hard copy records to assure valid data coalescence. Since individual animal was randomly allocated to treatment, treatment physically applied and all data gathered at the individual animal level, animal was considered the experimental unit for all dependent variables reported. Frequency distributions were determined utilizing PROC FREQ of SAS (SAS Version 9.3, SAS Institute, Cary, NC). Continuous variables were modeled using PROC MIXED of SAS including the random effect of pen nested within kill day. Liver abscess score and rumen health scores, and quality grade were modeled utilizing ordinal logistic regression similar to the procedures described by Osterstock et al. (2010) using PROC GLIMMIX of SAS with the cumulative logit link and a multinomial

distribution specified. Hepatic abscess scores were coded as 1=Normal, 2= A-, 3=A, 4 =A+, rumen health scores coded as 1= Normal, 2= Mild, and 3=Severe, and quality grade scores were coded as 1=all grades below Select, 2=Select, 3=Choice, and 4=Prime. Least squared means are reported for continuous variables and odds ratios and their respective 95% confidence intervals are reported for ordinal variables. Odds ratios generated in PROC GLMMIX can be interpreted as the odds of an increase in score (more severe) of M.e. treatment vs. Con. Significance was declared at  $P < 0.05$ .

## Results

Initial weight and days on feed were not different between treatments ( $P = 0.83$ ,  $P = > 0.99$ , respectively, Table 1.). Similarly, there were no significant differences observed in carcass adjusted final live weight between Con and M.e. treatments ( $P = 0.79$ ). All carcass characteristics measured were similar between the two treatment groups including hot carcass weight, 851 lbs. vs. 853 lbs. for Con and M.e., respectively ( $P = 0.816$ ). The ordinal odds ratio of a M.e. carcass having an improved USDA quality grade was not significant (Estimate: 1.04, 95% C.L. 0.749-1.468,  $P = 0.783$ ) and overall 59.1% and 57.8 % of M.e. and Con carcasses graded Prime or Choice.

Results of gross pathological observation at slaughter showed that 73.50% and 74.65 % of cattle from M.e. and Con, respectively were found to have grossly normal livers free from evidence of abscesses or other abnormalities (Table 2). Of cattle receiving the M.e. treatment at arrival, 14.0% were found to display a liver abscess of varying severity at the time of slaughter

compared to 14.2% of Con cattle. The ordinal odds ratio of a M.e. treated animal having a more severe liver abscess score was not significant (Estimate: 0.96, 95% C.L. 0.733-1.259,  $P=0.771$ ).

Rumen health scoring based on the gross appearance of the ruminal epithelium and the presence of rumenitis lesions indicated that 75.6% and 79.2% of M.e. and Con cattle had healthy rumens free from abnormalities (Table. 3). Overall, 7.96% and 8.27 % of M.e. and Con cattle were observed with evidence of an altered rumen epithelial health status. Rumens not able to be evaluated according to the health score system due to condemnation, identification failure, or visualization failure were denoted as Unknown (16.44% and 12.52% for M.e. and Con, respectively). The ordinal odds ratio of a M.e. treated animal having a more severe rumen health score was not significant (Estimate: 1.01, 95% C.L. 0.625-1.6.31,  $P=0.96$ ). Of the cattle with a liver abscess of varying severity, 7.9 % of M.e. and 6.9% of Con cattle were observed with some kind of rumen lesion.

## Discussion

The effects on rumen metabolites and micro-environment as a result of dosing various types of beef and dairy cattle with the commercially available strain of *Megasphaera elsdenii* (NCMIB 41125) have been investigated thoroughly by previous authors<sup>3,9,11,12,18</sup>. In general, the results of these works show a consistent ability of the *Megasphaera elsdenii* strain to beneficially modulate ruminal fermentation. However, the degree and timeframes of the benefit compared to control animals are variable. The objective of this study was not to attempt to reproduce or replicate these works, but rather, assess the terminal effects the product in a large pen feedlot setting, in yearling feedlot cattle representative of a large portion of the US fed cattle population today.

The yearling crossbred steers utilized in this study were assembled from two main geographical regions: the southeastern United States and Eastern Colorado. The nutritional background of these cattle was not documented or known by these investigators, as is common for most cattle entering the commercial feeding system<sup>4</sup>. However, given the initial weight of these animals, it is possible that a proportion of the population had been previously exposed at some level to a milled concentrate ration; hence a proportion of the animals may have been adapted to diets containing a proportion of concentrate rather than a purely forage based diet. Similar animals were utilized by Miller (2013) and Drouillard et al. (2012) for the purpose of their investigations. Similar to Drouillard et al. (2012), this investigation failed to detect a significant difference in the final body weight of steers orally dosed at arrival with *Megasphaera elsdenii*. However, ADG, final body weight, DMI, and feed efficiency has been shown to be significantly improved over an 85-day receiving period in light weight, high-risk cutter bulls and steers receiving *Megasphaera elsdenii* at processing<sup>12</sup>.

Total liver abscess rates were similar to those recently reported for the U.S. killed beef population by McKeith et al. (2012)<sup>10</sup> and were less than those reported by Rezac et al. (2013)<sup>15</sup> for yearling cattle fed in the same region. The current study showed no significant effect of treatment on liver abscess rates or severity. This is consistent with observations made by others investigating the use of *Megasphaera elsdenii* NCMIB 41125.<sup>3,9</sup>

Results from the gross pathologic investigation of the rumen epithelium indicate a lack of treatment effect on the gross outcomes of ruminal health measured here. Data concerning prevalence rates of gross rumen pathology in the published literature is limited. Classical reports leading to the establishment of the rumenitis-liver abscess complex have reported ruminal lesion prevalence rates ranging from 26-55% in feedlot cattle<sup>7,16</sup> however, Leeuw et al. (2009) reported



no significant differences in mean ruminal health score between control cattle and cattle treated with *Megasphaera elsdenii* and subsequently fed a high or low roughage ration.

This study reported here indicates that dosing crossbred yearling steers on arrival with a *Megasphaera elsdenii* (NCMIB 41125) DFM did not result in a significant difference in carcass performance or gross pathological indicators of rumen health. However, further investigation utilizing different demographics of cattle is warranted to correctly ascertain the most appropriate use for *Megasphaera elsdenii* (NCMIB 41125) as a management tool.

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**Table 4-1. Effect of an oral drench of a commercially available *Megasphaera elsdenii* (NCMIB 41125) probiotic at the time of initial processing on performance and carcass characteristics of yearling feedlot steers**

Item	Treatment		SEM	P-Value
	Con	M.e.		
n	1,621	3,242	-	-
Initial Wt. (lbs.)	823	820	9.4	0.83
Final Wt. (lbs.) <sup>1</sup>	1,322	1,326	14.7	0.79
Days On Feed	141	141	2.7	>0.99
Carcass Wt. (lbs.)	851	853	8.5	0.81
Loin Area (in <sup>2</sup> )	13.3	13.4	0.16	0.47
Fat Thickness (in)	0.43	0.44	0.008	0.68
Yield Grade	2.96	2.91	0.056	0.39

<sup>1</sup>Individual final live weight calculated as individual hot carcass weight divided by lot average dressing percentage

**Table 4-2. Frequency counts and percent prevalence of liver status scores at slaughter in yearling feeder steers dosed with 100ml of a commercially available *Megasphaera elsdenii* (NCMIB 41125) probiotic culture at the time of processing.**

Liver Status <sup>1</sup>	Treatment			
	Con		M.e.	
	Frequency	Prevalence, %	Frequency	Prevalence, %
Normal	1,210	74.65	2,383	73.50
A-	66	4.07	160	4.94
A	75	4.63	141	4.35
A+	89	5.49	153	4.72
Cirrhosis	8	0.49	7	0.22
Fluke/Parasite	36	2.22	59	1.82
Telangiectasis	22	1.36	45	1.39
Contamination/Misc.	112	6.91	248	7.65
Unknown	3	0.19	46	1.42
n/total	1,621	100.0	3,242	100.0

<sup>1</sup>Gross liver pathology at slaughter: Normal: livers free from abscesses, parasites, or other pathological abnormalities. A-: livers which displayed  $\leq 2$  abscess  $\leq 2$  cm in diameter, or resolved abscess scars. A: livers which displayed 2 to 4 abscesses 2 to 4 cm in diameter. A+: livers displaying  $\geq 1$  abscesses  $> 4$  cm in diameter or  $> 4$  abscesses  $> 2$ cm in diameter, adhesions to the body wall or other organs, or a ruptured abscess. Fluke/Parasite: livers displaying evidence of infestation by flukes (*Fasciola hepatica* or other). Misc.: Liver condemned for miscellaneous reason or contamination. Telang: livers displaying gross pathologic evidence of telangiectasis. Cirrhosis: livers displaying gross pathologic evidence of cirrhosis.

**Table 4-3. Frequency counts and percent prevalence of rumen status scores at slaughter in yearling feeder steers dosed with 100ml of a commercially available *Megasphaera elsdenii* (NCMIB 41125) probiotic culture at the time of processing.**

Rumen Status <sup>1</sup>	Treatment			
	Con		M.e.	
	Frequency	Prevalence, %	Frequency	Prevalence, %
Normal	1,284	79.21	2,451	75.60
Mild	114	7.03	218	6.72
Severe	9	0.56	21	0.65
Scar	11	0.68	19	0.59
Unknown	203	12.52	533	16.44
n/total	1,621	100.0	3,242	100.0

<sup>1</sup>Gross rumen pathology at slaughter: Normal: Gross appearance of healthy epithelium with thick, lush papillae with no signs of inflammation, ulceration, or other insult. Mild: Consolidated portions of the ruminal mucosal surface displaying short (relative to normal) or denuded papillae. Severe: Active rumenitis lesions; focal or multifocal ulcerations characterized by demarcated, irregularly circular, depressed, red, foci or healed ulcerations (scars) characterized by focal or multifocal puckered scars (star shaped) devoid of papillae [15].

## **Chapter 5 - Monitoring carcass bruising for assessment of handling and welfare in commercial packing plants<sup>1</sup>**

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## Introduction

Providing consumers with safe, wholesome, and high quality beef that has been produced in a responsible and humane manner is paramount to the sustainability of the beef industry. An integral part of this is humane handling of animals at each stage of their life. Through market signals as well as the hard work of progressive stakeholders and animal welfare experts the manner in which animals are handled has seen drastic improvements over the last decade. Since 1999, many large meat buyers including restaurant chains such as McDonald's, Wendy's, Burger King, and Whole Foods have enacted animal welfare auditing programs to monitor their supply chain with special emphasis on the packing plants where their products are processed and procured (Grandin and Deesing, 2008) and it is estimated that approximately 90% of commercial beef and pork slaughter plants are audited by major customers (Grandin, 2007). Though there are several important objective measurements to be considered when assessing how animals are handled, evaluating carcasses for the presence of bruising at slaughter can be extremely valuable. Quantitative economic losses due to carcass bruising in cattle have been estimated to be \$22.4 million (Rosse, 1974); however, this figure needs to be revisited given the marked changes in production practices since the 1970's. Besides resulting in economic loss, bruising is also an indication of compromised welfare (Jarvis et al., 1996). However, in order to use bruising (or any other variable measured at slaughter) to drive outcomes based decisions for changes in management, handling, and facilities there are certain criteria that must be satisfied:

- 1) Methods and scoring systems must be documented and consistent.
- 2) Methods and scoring systems must be developed in such a manner that the data which are yielded is able to be used in outcomes based decisions.
- 3) Methods must be easily and efficiently carried out in a commercial

setting. 4) Data must be compiled over time to establish baseline incidence or prevalence and define the “normal” range of the outcomes measured.

The objectives of this paper are two-fold: 1) Provide a review of the factors which influence carcass bruising and compare and contrast different systems which have been utilized by investigators to capture data 2) Introduce a newly developed bruise scoring system

## **General**

Bruises are a classification of hematoma and are typically caused by direct trauma to the area in which they occur. The gross appearance of the lesion is due to rupture of local capillaries, arterioles or venules by the forces of trauma to the affected area allowing blood to escape into the surrounding tissues and interstitium. As it pertains to cattle, this means that a bruise can occur up until the point of exsanguination. The mechanism for resolution of bruises in cattle is dependent of time and the severity of the initial trauma. Though gross examination of bruises provides a relatively low level of specificity for estimating time frame at which a particular observed bruise occurred (bruise age) at chain speed, generalities can be made based gross pigmentation characteristics; bruises caused by trauma occurring within the last few hours will display a bright red coloration due to the high concentration of oxygenated intact hemoglobin and bruises resulting from trauma occurring > 24h pre-slaughter will display a different pigmentation due to the phagocytosis of erythrocytes from tissues by the macrophage-monocyte system and breakdown of hemoglobin into hematin, bilirubin, and hemosiderin which display orange-red, yellow, and brown pigments, respectively(Zachary and McGavin, 2012).

Histologic examination of bruised tissues allows for a relatively sensitive diagnostic indicator of bruise age and has been reported experimentally by McCausland and Dougherty (1978). In

carcasses sampled at Australian slaughter houses, they concluded that between 43 – 90% of bruises occurred after cattle arrived to the abattoir. The histological examination of bruises is likely not plausible for implementation in commercial slaughter plants on a routine basis, however maybe quite useful in a research setting or when a lot of cattle is severely affected by bruises and a case investigation is warranted to deduce the source point of bruises. Assays for determination of bruise age utilizing bilirubin concentration have also been reported; however yield low diagnostic sensitivity for bruises < 48h old (Shaw, 1977).

### **Sources of Variation**

Many factors have been shown to have a significant effect on the prevalence of carcass bruising observed at slaughter. Jarvis et al. (1995) examined the influence of source, sex class, and handling on bruising in cattle from two UK slaughterhouses. Overall prevalence of bruising was remarkably high (97%) and cattle sourced from auction markets had a significant higher median number of bruises per carcass than did cattle sourced directly from farms. Slaughter lots of heifers, and bulls had the least amount of bruising at slaughter compared to lots of steers, mixed steers and heifers within a common source. Similar sex classification influence was observed by Weeks et al. (2002) and the authors hypothesized this was likely due to a number of factors including hide thickness, fat depth, temperament, and response to stimuli. Significant correlation was found between the use of driving aids and the occurrence of bruising of multiple areas of the carcass.

The presence of horns has been linked with the occurrence of bruises at slaughter (Shaw et al., 1976; Wythes et al., 1985). Shaw et al. observed that trim losses due to bruises from horned cattle were nearly numerically double that of the trim losses associated with polled cattle (2.5 vs

4.0 lbs, respectively). Dehorning has been attributed to short term reductions in performance but not over the entire feeding period, however depending on method, welfare and pain incurred due to the procedure can be of major concern (American Veterinary Medical Association, 2012) . By far, the most logical solution for resolving bruises caused by horns is the increased use of polled genetics in cow/calf production systems. Reported prevalence of the presence of horns on cattle slaughtered in the U.S. has decreased from 31.1% in 1991 to 23.8% in 2011 (McKeith et al., 2012).

Higher stocking densities during transport to the slaughter house have been shown to significantly increase carcass bruising, although the physical pen location within the transport truck was not shown to be a significant source of variation (Tarrant et al., 1988). Considering the difference in the design of the trucks examined in this study compared to the traditional “cattle pots” that are an industry standard in the U.S., the influence of compartment location during transport on subsequent bruising should most likely be reevaluated.

In the U.S., Hoffman et. al (1998) examined the associations carcass bruising with transportation distance to slaughter and concluded that the carcasses of mature beef cows marketed through livestock auctions that conducted first-point testing for brucellosis were observed with a greater number and severity of bruises than their cohorts sourced from ranches or auction markets not conducting first –point testing, this increase was exacerbated when cows were transported >325km. The authors concluded that the repeated handling and restraint of the first-pointed tested cows resulted in the increased prevalence and severity of bruising.

Weeks et. al (2002) observed a significant negative correlation with bruising and mean rate of sale at commercial auction markets. That is, those auction markets that sold more head per minute tended to have less bruises at slaughter. The auction market with the least amount of

bruising and highest sale rate also had the most handlers and the lowest prevalence of animals being hit with driving aids, 1.8%, which is well below the 10% maximum limit set forth in current U.S. Beef Quality Assurance (BQA) standards. This observation is important in that it shows that quick and efficient movement of cattle is possible while maintaining proper handling techniques. In personal experience, this author has observed similar outcomes in auction markets and in feedlots when conducting BQA assessments, such that the handling systems for which throughput rate was the fastest also tended to be the handling systems in which driving aid usage was the least. These observations also demonstrate the importance of labor; adequate labor to appropriately operate the handling system should always be readily available so that any single handler does not become overwhelmed by the task and resort to relying on constant driving aid usage or other unacceptable handling measures in order to keep throughput at the needed level. Inappropriate driving aid usage can also be a source of carcass bruising and is usually directly manifested in the form of stick bruises. Weeks et al. observed a 13% prevalence of stick bruises at slaughter in cattle sourced from auction markets which was significantly higher than cattle from any other source. Prevalence of stick bruises was also significantly different by sex such that 6.9% of steers were observed with a stick bruise, over twice that of heifers (2.5%), suggesting possible differences in responses to stimuli from handlers. Mechanical or structural failure of equipment and design in handling systems may be the most significant source of bruises. Ends of corral piping that are not properly ground down and rounded over leaving sharp or angular leading edges can cause severe trauma to animals that impact them. Additionally, any 90° turn that has to be negotiated by animals could result in trauma and therefore bruising to the rib and/or loin areas (Grandin, 1980). Other equipment and facility sources of trauma can include the vertical sliding back gates of cattle pens that are not

raised to an adequate height or improperly designed or used gates and “no-backs” in alley ways that are not properly adjusted. In general, the zone 28 - 52” above the floor in all handling facilities is considered the “bruising danger zone” and should be examined for surfaces and objects that can cause trauma and subsequent bruising (Livestock Conservation Institute, 1974).

## **Scoring Systems**

This section intends to review the most commonly found carcass bruise scoring systems found in the published literature to date as well as introduce a new system developed and utilized by these authors.

### ***The Australian Carcass Bruise Scoring System***

Globally, the most widely used and reported system for assessing bruises at the time of slaughter is the Australian Carcass Bruise System which was first developed and implemented in 1973 in Queensland Australia and is described in detail by Anderson and Horder (1979). This system was developed and implemented in order to provide consistent and documentable methods for assessing bruises and correct what the authors refer to as “suspect methodology and unsubstantiated conclusions”. Collected data points in respect to bruising are as follows:

- Severity
  - Slight (S)
    - 2-8cm in diameter
  - Medium (M)
    - 8-16m in diameter
  - Heavy (H)

- > 16cm
- Depth (abbreviated d, Does the bruise involve more than surface tissue?)
- Resulting in 6 possible classifications ( S, Sd, M, Md, H, Hd)
- Location
  - Butt
  - Rump and Loin
  - Rib
  - Forequarter
  - Back
  - Hip
  - Pin
- Approximate shape and location of the bruise is drawn on a cartoon of the carcass provided on the scoring sheet. One carcass per score sheet.
- Weighting factor assigned based to bruise based on severity and depth as follows and total bruising score for carcass summed:
  - S: 1
  - Sd:3
  - M:3
  - Md:5
  - H:5
  - Hd:7

The weighting factors for bruise classifications were assigned based on regression equations derived for amount of trim associated with each bruise classification such that it was estimated

that a total bruise score of 8 resulted in approximately 1 kg of trim loss. The authors indicated that this system was able to be carried out with relative ease by one investigator at the rate of 40-50 carcasses per hour.

Though implementation of this system is well documented and widespread application in the majority of U.S. beef slaughter houses for commercial monitoring is not likely feasible. The greatest issue with this system is that the chain speed (carcasses/hour) for which the system was designed is 8-9 times slower than many modern U.S. slaughter plants (390/hour). This will either severely limit the accuracy at which a single investigator can conduct scoring or require several more investigators working in an alternating fashion. Also, the use of one sheet per carcass is not practical, as scoring of one hour's worth of carcasses in most commercial U.S. plants would result in an unmanageable amount of paper (> 300 pages!). Secondly, the weighting factors, which are derived from trim estimates, are likely confounded greatly by location, which is recorded in this system but not accounted for in the regression analysis used to calculate them. It has been observed by this author that severe bruises (according to the later introduced HAP<sup>TM</sup> bruise scoring system) that occur in the flank of hip region are trimmed to the greatest extent according to the direction of USDA personnel as compared to severe bruises occurring in other areas such as dorsum of the carcass. Furthermore, the appearance of severe bruises occurring on the midline of carcasses (scored before carcass splitting) are greatly altered after the carcass is split therefore augmenting the gross appearance of abnormality and decreasing the amount of trim associated with the bruise that is dictated by USDA inspection personnel.



Regardless of the issues with current commercial application of this system in the U.S., it has yielded immensely important experimental data since its inception and provided substantial objective information on the necessity for proper animal handling and facility design.

### ***The National Beef Quality Audit Scoring System***

Since 1991, the U.S. has conducted the National Beef Quality Audit (NBQA). Data from this comprehensive survey is critical for the continued advancement of industry practices and provides important information to researchers and industry leaders. A portion of this program includes the collection of carcass bruising data. The most recent NBQA data from 2011 is reported by McKeith et al. (2012). The scoring system currently utilized is as follows:

- Number of bruises per carcass
  - 0,1,2,3,4,5+
- Location
  - Round
  - Loin
  - Rib
  - Chuck
  - Flank/Plate/Brisket
- Severity (1-10)
  - Minimal (1-3)
  - Major (4-6)
  - Critical (7-9)
  - Extreme (10)

This system yields good information pertaining to the overall prevalence of bruising as well as general location and severity and works well for information as it pertains to the NBQA.

However, in order to identify the occurrence of systematically incurred bruises, such as those occurring as a result of a mechanical failure or breakdown of handling equipment and systems, more precise location identification is warranted. Moreover, the application of a 10 point ordinal scale for severity may require investigators to imply a great degree of subjectivity (i.e. is there a biologically significant difference between a 3 and 4, 6 and 7, or 9 and 10 and if so is the difference of the same magnitude?) As with the Australian system, this systems yields very valuable data for which it was designed and can be implemented at the chain speed of modern U.S. plants with relative ease by one investigator.

### ***Harvest Audit Program™ Scoring System.***

A new score system that is proposed for use in the periodic evaluation of carcass bruising in commercial slaughter plants is proposed by this author. This system was designed with simplicity, consistency, and practical application of the data yielded in mind. The system is implemented with following criteria and methods:

- Location (1-9)
  - Location is denoted by assignment of a grid number that is denoted on provided cartoon that correspond to the following anatomical landmarks: . 1: Right hind limb - cranial border is a transverse line at the level of the lumbosacral junction and extends caudally including the distal right hind limb. The medial border of this region bisects the round on the right hindquarter. 2: Midline tailhead – cranial

border beginning at the lumbosacral junction and extending caudally. Lateral borders bisect the left and right rounds. 3: Left hind limb - cranial border is a transverse line at the level of the lumbosacral junction and extends caudally including the distal left limb. The medial border of this region bisects the round on the left hindquarter. 4: Right barrel – cranial border is a transverse line at the level of the 7<sup>th</sup> thoracic vertebrae extending caudally to a transverse line at the lumbosacral junction. The medial border of this region is the lateral border of the right epaxial muscles. 5: Midline barrel – cranial border beginning at the 7<sup>th</sup> thoracic vertebrae extending caudally to the lumbosacral junction. 6: Left barrel - cranial border is a transverse line at the level of the 7<sup>th</sup> thoracic vertebrae extending caudally to a transverse line at the lumbosacral junction. The medial border of this region is the lateral border of the left epaxial muscles. 7: Right forelimb – caudal border is a transverse line at the 6<sup>th</sup> thoracic vertebrae extending cranially including the distal right forelimb. The medial border of this region bisects the chuck on the right side. 8: Midline shoulder – caudal border is at the level of the 6<sup>th</sup> thoracic vertebrae and extends cranially. Lateral borders of this region bisect the left and right chuck. 9: Left Forelimb - caudal border is a transverse line at the 6<sup>th</sup> thoracic vertebrae extending cranially including the distal left forelimb. The medial border of this region bisects the chuck on the left side. This cartoon is provided in upper right corner of the scoring sheet or on an (8.5“x 11”) laminated sheet (See Appendix C.).

- Severity / Size; The appropriate mark (-,0,+) is placed on the location of occurrence.

- Minor (-)
  - $\leq 2$  inches in diameter or 3 square inches of focal area
- Moderate (o)
  - 2-6 inches in diameter or 3 to 28 square inches of focal area
- Severe (+)
  - $> 6$  inches in diameter or  $> 28$  square inches of focal area
- Carcasses with multiple bruises are denoted by applying the severity/size score to the location of the bruise (See below score sheet example).
- In the case of multiple bruises throughout one location, the most severe is recorded.
- If a bruise occurs along the margins of multiple locations, the location of which the majority of the bruise is contained in is denoted.
- Examples: See Appendix A and B.

The HAP™ Bruise score system has been implemented on the  $> 18,000$  carcasses in commercial packing plants the U.S. Data reports have been generated for the management teams commercial feedyards and packing plants and have received positive feedback. One case in particular pointed out the practical implications of such data: A commercial cattle feeder received reports of bruising from the packer in their calf-fed Holstein cattle. After bruising data according to the HAP™ system on several lots of cattle were gathered, systematically occurring bruises were located in a high prevalence along the dorsum of cattle (zones 2,5, and 8). Further investigation found that truck drivers were not raising the rear gate to a height that allowed for the taller Holstein cattle to exit without striking their back. Adjustments were made and the majority of the

problem was corrected; A positive outcome for the feedyard, the packing plant and most importantly, the cattle.

## **Conclusions**

Carcass bruising is an important outcome for assessing handling and welfare of cattle at slaughter plants and variation can be attributed to multiple factors in the supply chain.

Depending on prevalence, severity, and location, bruises can result in significant economic loss and can indicate a compromised state of welfare. A shortcoming of all scoring systems is accurate determination of timing of bruise occurrence. Comprehensive slaughter assessments and audits should include the measurement of carcass bruising; however, upper critical control limits according to a common scoring system must be set and agreed upon by multiple industry stakeholders including producers, packers, veterinarians, and animal welfare experts.

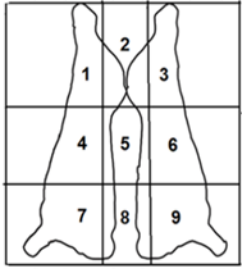
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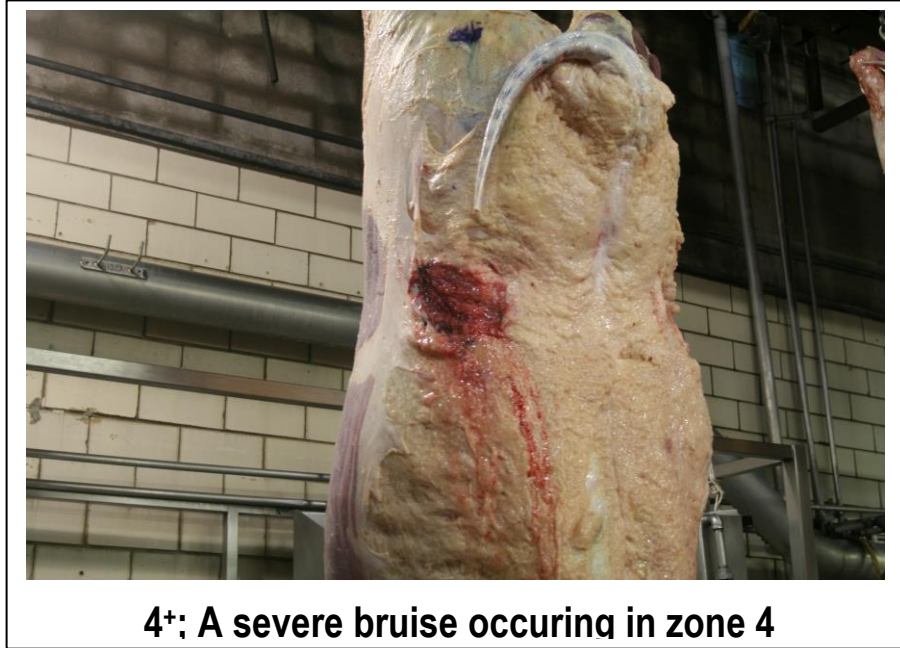
# Appendix A - Harvest Audit Program™ Bruise Scoring Data Capture Form

Harvest Audit Program - Kansas State University									
<b>Bruising Evaluation</b>									
					(B-) < 2 inches				
Date: _____					(B0) < 2-6 inches				
Location: _____					(B+) > 6 inches				
Initials: _____									
Seq. #:									
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

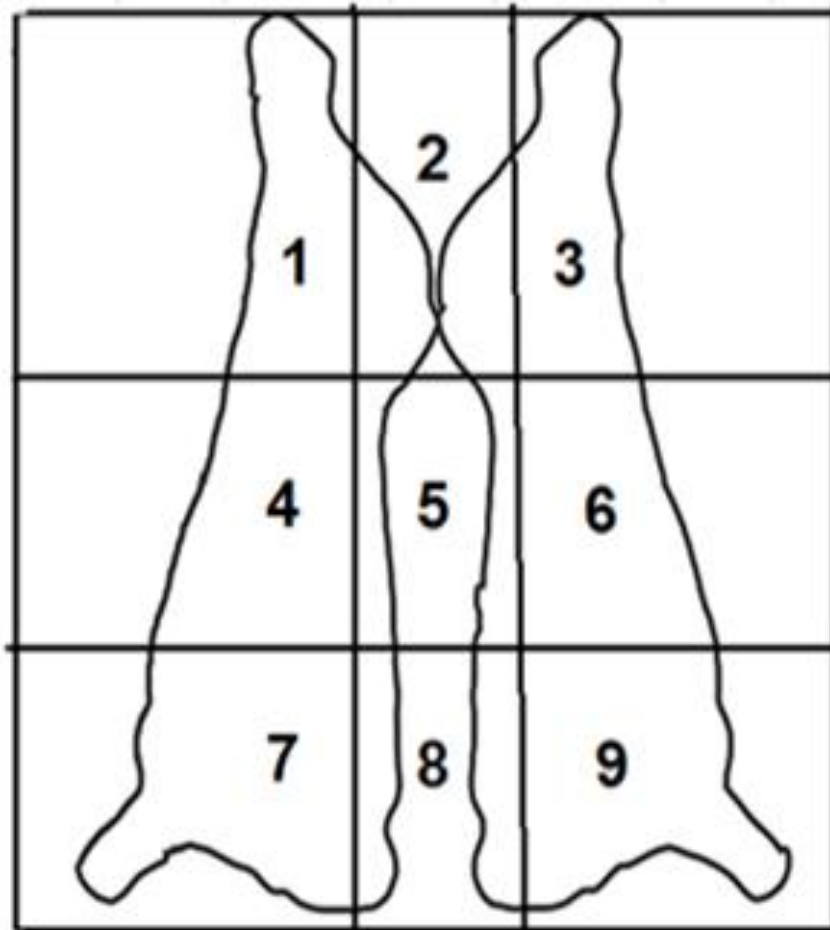




**Appendix B - Photograph example of a carcass bruise according to the Harvest Audit Program™ bruising score system.**



**Appendix C - Anatomical Bruise Location Cartoon for the Harvest Audit Program™ Bruise Scoring System.**



# **Appendix D - Beef Cattle Institute Harvest Audit Program™**

## **Slaughter Data Collection Standard Operating Procedure**

### **I. Training**

- a. All personnel collecting data must be trained according to the standard operating procedures herein as well as any and all other supplementary training materials prior to collecting data for an official experiment.
- b. For each organized experiment, a Training Acknowledgment Form must be signed and filed by all personnel taking part in data collection procedures. It is the responsibility of the study investigator / co-investigator to insure proper training of all personnel.

### **II. Communication, Planning, and General Conduct**

- a. An open line of communication must be established among the cooperating feedyard from which cattle will be shipped, packing plant personnel, and data collection Team Leader (**TL**) to assure information sharing on cattle shipping schedules and when cattle are expected to be killed.
  - i. Communication items to be determined:
    1. Date and time of harvest
    2. Identification of cattle/lot/pen
    3. Number of cattle
    4. Data collection TL

- ii. Feedyard personnel may include general manager, cattle manager, and shipping manager
  - iii. Packing plant personnel may include plant manager, slaughter manager/supervisor, and procurement personnel
    - 1. Note: Some packers may require corporate approval to enter packing facilities and time sensitive paperwork may be required.
- b. On the day of slaughter data collection, crew should be on site minimum of 1 hour prior to expected kill time of cattle. The TL should immediately make contact with a kill floor supervisor/superintendent or scale house operator to obtain an official plant line up in order to determine the plant carcass number at which target cattle begin and end. This information should be dispersed to all crew members.
- c. In general, all crew members should be in place at their respective stations at a minimum of 15 minutes or about 50 carcasses prior to the beginning of target cattle, respective to their location on the processing line.
- d. Crew members must be respectful of the working space of all plant personnel. It is vital that observations do not impair the normal and efficient processes of the plant. **Above all, observe all personal and food safety regulations mandated by the USDA and plant personnel. Adhere to all posted signage regarding personal hygiene, personal safety and food safety. If any uncertainties arise consult the team leader and/or a plant supervisor or superintendent (Blue or Yellow hard-hat).**

- i. A hair net, hard hat, ear plugs, steel-toed rubber boots, and a clean frock at all times on the kill floor. If near areas where lactic acid is being utilized, safety glasses are also required and always strongly recommended regardless of plant policy.**

### III. Harvest Data Collection

- a. Start Up

- i. The TL, quality control officer (QC), or crew member will be stationed near the knock box to identify the beginning of the target cattle and proceed with the carcass through the plant to ensure crew members properly identify the beginning of the target cattle.

- ii.

- b. Rumen

- i. Rumen Identification

- 1. Individual identification of each rumen is accomplished by marking the weasand clamps attached to the esophagus of each animal with the individual carcass number assigned to the carcass by the plant. The weasand clamp is attached “upstream” on the chain from the actual rumen data collection point.
    - 2. The crew member assigned to rumen data collection should arrive as early as possible to their station and communicate plans with the “weasand rodders” to allow for smooth operation. If possible, pre-number all weasand clamps with the projected carcass numbers of the target cattle

- a. It is advantageous to begin the numbering 15-20 carcasses prior to the beginning of target cattle to assure that the hand off of marked clamps to the rodders is accomplished in an efficient and accurate manor.
  - b. It is usually sufficient to only mark the clamps with the final 3 digits of the carcass number
3. The crew member will hand off individual marked clamps to the rodders and ensure that the number on the clamp corresponds with the carcass number to which it is applied.
4. If a clamp is dropped or mistake is made a blank clamp should be used. If a numbered clamp is placed on the wrong carcass, a note should be made and the proper sequence regained.
  - a. Make sure to communicate this to weasand rodders.

ii. Rumen Grading

1. Rumen grading is done by a two person crew. One reads and records the weasand number, and if possible communicates the number to the second person on the crew, who scores the rumen.
2. One crew member will be stationed at the point on the processing line prior to the removal of the esophagus from the rumen and prior to the rumen grading crew member to identify the numbered weasand clamps and confirm the number with the grader either verbally or by recording the number on the a blank sequence sheet. This will be determined by plant design.

- a. Crew members should note that some rumens will be condemned and therefore will never make it to this point in the processing line.
3. The crew member charged with grading the rumen is stationed on the processing line after the rumen is opened and the paunch is drained; however, specific location may be variable according to plant design.
  - a. If verifying the carcass number verbally with the crew member reading clamps, the grader will record the number dictated to them and assign a grade according to the scoring system.
  - b. If the crew member identifying the numbered weasand clamps is also recording them on a blank sequence sheet, the grader will simply assign a sequence number in the order that the rumens pass them and numbers will later be matched according to weasand clamp number identifier's sheet.
4. The grader will assign a grade to each rumen in the following scoring system:
  - a. 0(Normal)= The lumen of the rumen exhibits a normal, healthy appearance. Papillae population appears healthy and lush. No signs of inflammation, ulceration, or scarring is present.

- b. 1(Mild) = A consolidated area of the rumen epithelium with sparse, short (<0.5 cm), or denuded papillae.
  - c. 2(Severe) = Focal or multifocal or diffuse active, unhealed ulcerative lesions.
  - d. 3(Skip)= Cannot visualize the rumen to assign a score Or identification of number is not possible; blank tag or smudged number.
    - i. If number identification is not possible a pathology score may still be assigned for group prevalence data.
  - e. 4(Scar) = A healed or resolved rumenitis lesion is visible. Healed lesions include scars and often have a “star” appearance.
  - f. 5(Condemn) = Rumen is condemned.
    - i. This distinction may only be made in specific plants where the crew members are stationed in close proximity to the gut table so that condemned rumens can be identified. Otherwise, these rumens will be classified as skips (3) when the data are recorded electronically and married with other results.
5. Rumen grader should take special care to examine the floor of the ventral sack of the rumen as well as the floor of the caudal sacks of



the rumen as these are the locations where lesions commonly manifest.

6. Photographic examples of rumen scores and score sheet examples may be viewed in Section D- 1.

### iii. Carcass Bruising

1. One crew member will be stationed at a point on the kill floor to observe the location and severity of bruises on carcasses. This location is typically immediately after weasand rodding and before evisceration. If a bruise is present, the crew member will record the plant carcass number of the carcass and assign a bruise score according to the following system:
  - a. Location of the bruise on the carcass is coded by assigning a number (1-9) associated with a grid overlaid on a bilateral cartoon of a beef carcass. Following assignment of bruise location, each bruise is then assigned a severity based on size. Bruises less than 2” in diameter were assigned a mild severity denoted as “-“, bruises from 2-6” in diameter were assigned a moderate severity denoted as “o” , and a severe grade, denoted as a “+”, was defined as a bruise encompassing an area on the carcass of greater than 6” in diameter.
  - b. Photographic examples of bruising scores and score sheet examples may be viewed in Section D-2.

#### iv. Lung Scoring

1. One crew member will be stationed at a point on the processing line to observe lungs for the presence and severity of bovine respiratory disease (BRD) associated lung lesions. Depending on plant design and regulations, this position may be on the walkway running parallel to the offal table or ground level next near USDA inspection line. The crew member will identify the carcass number and then assign a lung score according to the following scoring system:

- a. 0 (Normal): No visible evidence of BRD pathology. All lung tissue appears healthy.
- b. 1 (Mild): BRD associated lesions are present and consolidated in less than 50% of any single lung lobe.
- c. 2 (Severe): BRD associated lesions are present and consolidated in greater than 50% of any single lung lobe OR any sign of pleural adhesions (could include missing lung tissue adhered to body wall).
- d. 3(Skip): Lungs were not visualized or carcass number identification was not made or incorrect.

2. Photographic examples of lung scores and score sheet examples may be viewed section D-3.

#### v. Liver Scoring

1. A crew member will be stationed on the offal table to assess the presence of liver abnormalities. This location is typically near re USDA inspection line. The crew member will assess abnormalities according to the following scoring system:
  - a. 0 (Skip) : Proper identification or visualization of liver is not possible.
  - b. 1 (Normal): Liver possesses no visual presence of abnormalities
  - c. 2 (A-):  $\leq 2$  abscesses,  $\leq 4$  cm in diameter, or resolved abscess scars
  - d. 3(A): 2-4 small abscesses 2-4cm in diameter
  - e. 4 (A+)  $\geq 1$  abscess  $> 4$  cm in diameter or  $> 4$  abscesses 2 cm in diameter
  - f. 5 (A+A) Abscess(es) adhered to body wall or GI tract
  - g. 6 (A+O) Open abscess
  - h. 7 (A+OA) Open abscess w/ adhesions.
    - i. For some studies 5,6, &7 scores may be consolidated as 4's (A+)
  - i. 8 (T) Visual gross pathological evidence of telangiectasia
  - j. 9 (C) Visual gross pathological evidence of cirrhosis
  - k. 10 ( F) Visual gross pathological evidence of liver flukes or other parasites. Often, dark blue or black sections are apparent on the surface that may resemble discolored

cracks in the hepatic tissue. Signs of fluke residing in the bile duct.

- i. Communicate with USDA inspection personnel and ask them to identify livers with flukes (they may refer to them as Distoma) or other parasites since signs may be slight or hard to see without inspecting the lumen of the bile duct.
1. 11 (X) Miscellaneous or Contamination. Livers may be condemned that display no signs of the above gross pathological diagnoses. Fecal matter, ingesta, hair or dirt on the liver.
2. If more than one abnormality is present, mark all that apply except in case of abscess where the most severe should be marked.
3. Photographic examples of liver abnormalities and score sheets may be viewed in Section D-4.

#### IV. Quality control

- a. If labor availability allows a designated QC officer should traverse the processing line assuring that crew members are recording the proper carcass number for their respective scores or act as relief in case a restroom break is needed.
  - i. Within any single day's data collection, a change in a crew member responsibility should be noted on the respective data sheet.
- b. If designation of a QC officer is not plausible, care must be taken to assure the proper sequence is kept by crew members recording pathology data or assigning

the numbered weasand clamps. **IT IS ALWAYS BETTER TO RECORD A “SKIP” AND INSURE THAT YOU ARE RECORDING A DATA POINT FOR THE PROPER CARCASS THAN ASIGN A DATA POINT TO THE WRONG CARCASS.**

V. Data recording, handling and storage

a. Plant data recording

- i. Clip boards will be loaded prior to arriving at the plant with enough data sheets to accommodate the day’s target cattle.
- ii. Prior to recording data on sheets, crew members must date, initial, and record the location of the plant in the provided area on the data sheets.
- iii. Crew members should assure that they have extra pens/Sharpie markers before beginning the day’s data collection.
- iv. The crew member charged with marking weasand clamps will use Sharpie Industrial Super Permanent Ink Fine Point markers.
- v. All others may use black or blue ink pens or Sharpie markers.
- vi. Upon completion of the days data collection, sheets shall be removed from clipboards, organized and filed in the portable file-box according to subject

b. Electronic data transcription

- i. Upon returning to the office, data should be transcribed to an electronic format (EXCEL Spreadsheet) ASAP and not more than 10 days after return.

- ii. Data transcription may be accomplished by one person or by a two person team.
  - 1. A two person team consists of one person who dictates data from data sheets and one person who records the dictation electronically on the Excel Spreadsheet.
- iii. Each lesion category for a day's data collection shall be recorded on a separate tab in the same workbook. Each data line (row) shall include the plant carcass number, the kill date, and the respective lesion score.
- iv. Raw electronic files shall be sent to the TL, Investigator, or Co-Investigator as soon as they are transcribed.
  - 1. A minimum of 3 separate copies of the raw electronic data files shall be made. These include but are not limited to:
    - a. Computer hard drive of the TL, Investigator, or Co-Investigator
    - b. External hard drive of the TL, Investigator, or Co-Investigator
    - c. A cloud-based system or network drive (Dropbox, Vet Med Drives, etc)
    - d. Flash Drives
    - e. Email server
  - 2. After electronic transcription, hard copies of the data shall be filed in a cabinet within a section designated to the respective study and organized by lesion category and collection date.

## VI. Equipment for Harvest Data Collection

- a. It is the responsibility of the TL to assure that all equipment necessary for data collection is obtained and packed for data collection trips.
- b. Personal Protective Equipment
  - i. Hard Hats
  - ii. Hair Nets
  - iii. Beard Nets
  - iv. Steel Toed Rubber Boots
  - v. Clean Frocks
  - vi. Ear Plugs
  - vii. Safety Glasses
  - viii. Latex Exam Gloves
  - ix. Palpation Sleeves
- c. Data Collection
  - i. Data sheets
  - ii. Clipboards
  - iii. Pens
  - iv. Sharpie Markers
    1. Regular
    2. Industrial
  - v. Portable File Box
- d. Miscellaneous

- i. Trash bags
  - 1. For dirty frocks
- ii. Laundry Soap
  - 1. If conducting a multi-day collection trip where frocks must be washed for use the next day.
- iii. Bleach
  - 1. If conducting a multi-day collection trip where frocks must be washed for use the next day.
- iv. PVC bibs / coat
  - 1. The crew member reading weasand clamps may wish to use these.



**Section D-1. Rumen Scoring examples and data capture forms.**

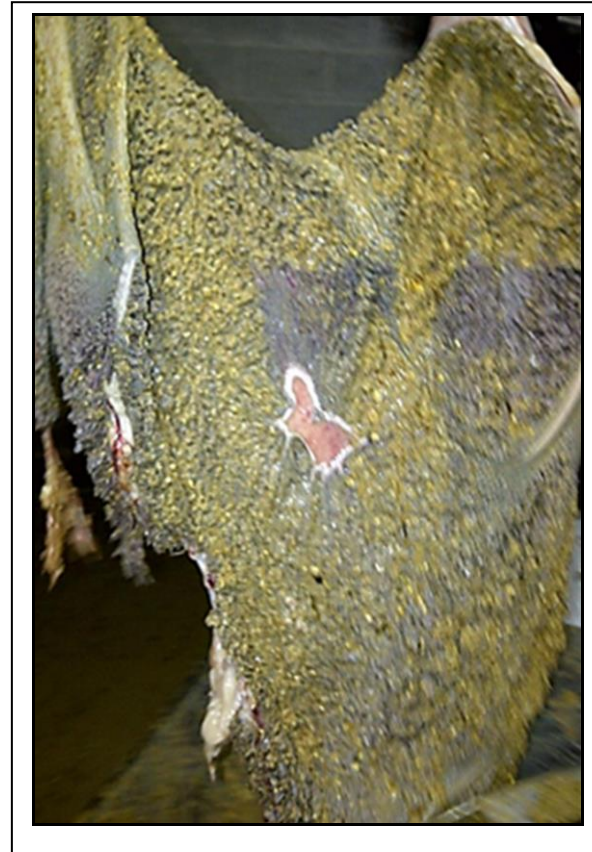
**a. “0” (Normal)** All surfaces of the rumen appear healthy with long and thick papillae. No lesions, scars, or areas of sparse, short, or denuded papillae are visible.



**b. “Mild”:** A consolidated area of sparse, short, or denuded papillae is present.



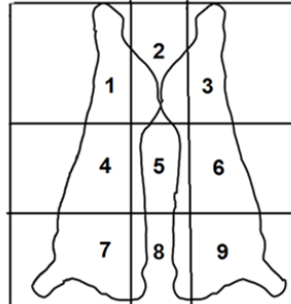
C. "Severe" Focal or multifocal lesions or scars.





**SectionD-2. Bruise scoring examples and data capture forms.**

Harvest Audit Program - Kansas State University									
<b>Bruising Evaluation</b>									
					(B -) < 2 inches				
Date:					(B0) < 2-6 inches				
Location:					(B +) > 6 inches				
Initials:									
Seq. #:									
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9
	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5	<input type="checkbox"/> 6	<input type="checkbox"/> 7	<input type="checkbox"/> 8	<input type="checkbox"/> 9



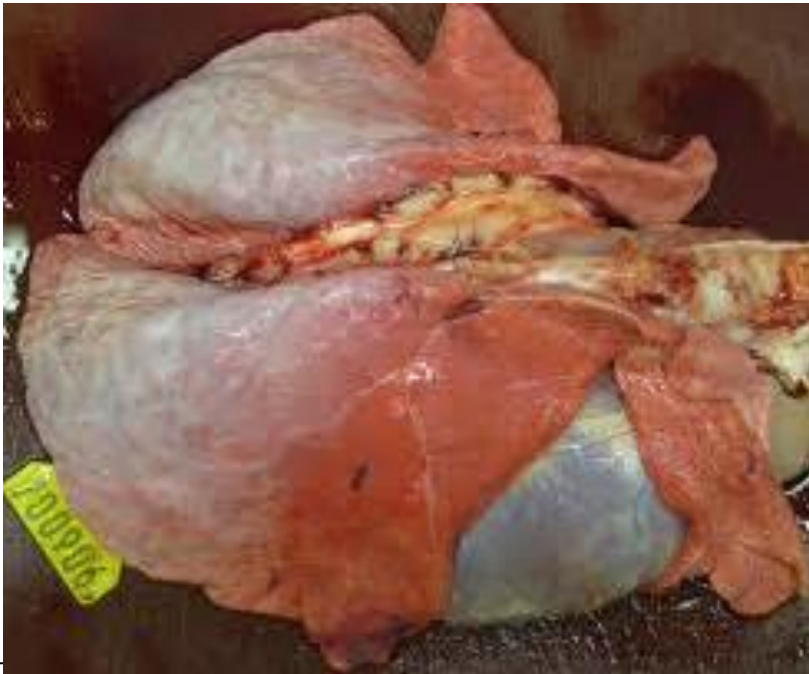
**6<sup>0</sup>; A bruise occurring in zone 6 of moderate severity.**

Note that this bruise has occurred in close proximity to the line between zone 3 and 6 and might be labeled as a zone 3 by some observers. The key here is consistency. If bruises are occurring in the same place, be sure to record make observations in a

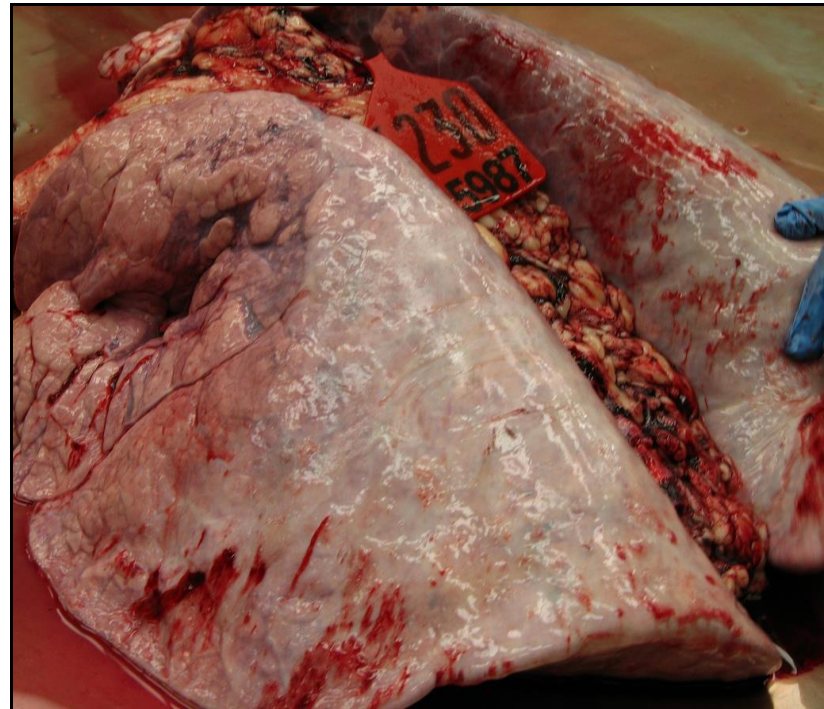
**4<sup>+</sup>; A severe bruise occurring in zone 4**

**SectionD-3. Lung Scoring examples and data capture forms.**

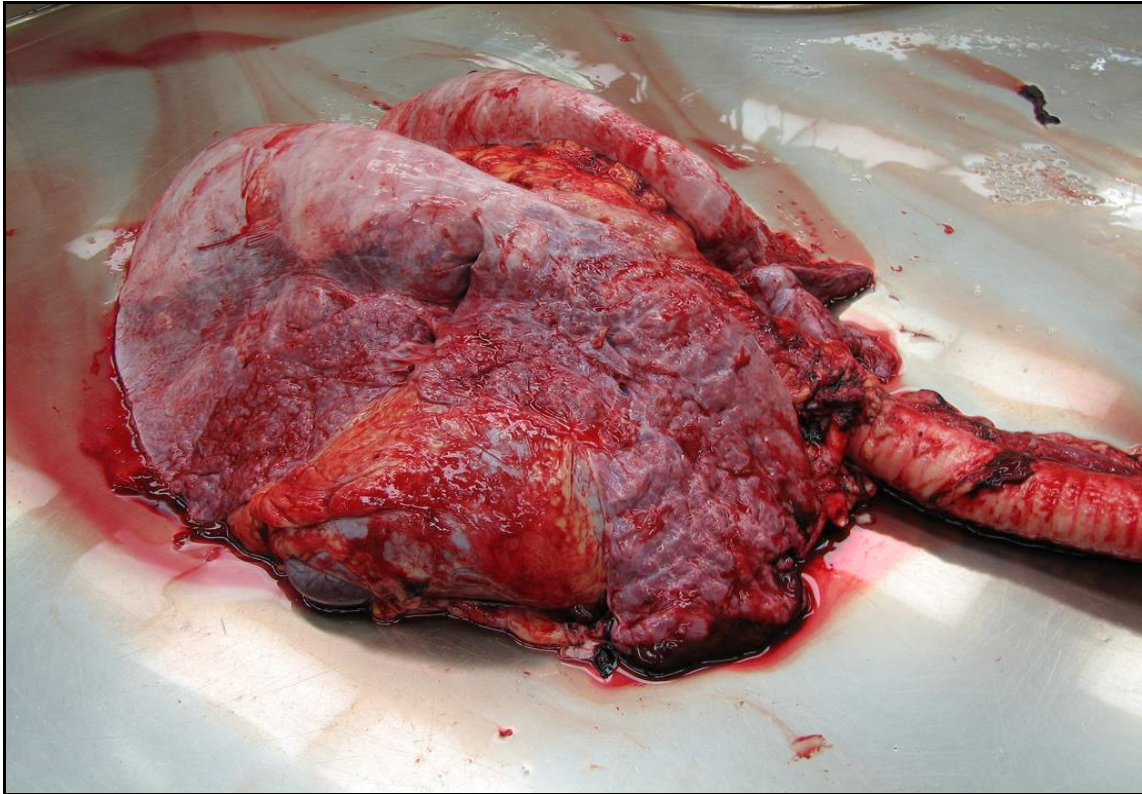
**“Normal” (0): Normal, healthy pink lung tissue throughout**



**“Mild” (1) : Partial consolidation and atelectasis of the left cranial lung lobe (<50%)**



**Severe (2): 90% Consolidation of the right cranial lung lobe and > 50% consolidation of the right middle and caudal lobes.**



**Kansas State University-Harvest Audit Program™**

<u>Lung Scoring</u>			Date	_____
S= Skip	0= Normal	1= <50% Consolidation (Any Lobe)	Location	_____
2= >50% Consolidation (Any Lobe)			Study ID	_____

			Initials _____		
Carcass	Sequence	Score	Carcass	Sequence	Score
	1			25	
	2			26	
	3			27	
	4			28	
	5			29	
	6			30	
	7			31	
	8			32	
	9			33	
	10			34	
	11			35	
	12			36	
	13			37	
	14			38	
	15			39	
	16			40	
	17			41	
	18			42	
	19			43	
	20			44	
	21			45	
	22			46	
	23			47	
	24			48	

EE: Entry Error TE: Technical Error

Page 1 of 15

**SectionD-4. Liver Scoring examples and data capture forms. Photo Credit: West Texas A&M University Beef Carcass Research Center**



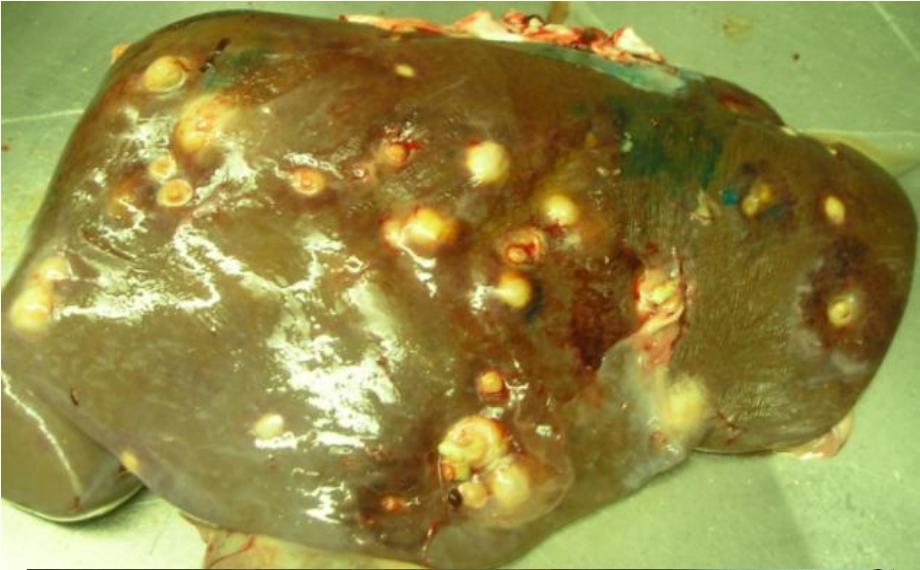
**A-: One small abscess**

**A: 2 abscesses approximately 3cm in diameter.**





**A+ & A+A: Multiple abscesses and abscess adhered to the body wall.**



**C: Cirrhosis**



**T: Telangiectasia**



**F: Liver Flukes (Distoma)**



**X: Contamination**



Kansas State University Harvest Audit Program™

Liver Scoring		
S=Skip	N=Normal	A= Abscess; A= Adhesion
T=Telang	C=Cirrhosis	O=Open Abscess
F=Fluke/Parasite	X=Misc./Contamination	

Date \_\_\_\_\_  
 Location \_\_\_\_\_  
 Initials \_\_\_\_\_  
 Study ID \_\_\_\_\_

Carcass	Sequence	Score	Carcass	Sequence	Score
	1	S N A- A A+ A+A A+O A+OA T C F X		19	S N A- A A+ A+A A+O A+OA T C F X
	2	S N A- A A+ A+A A+O A+OA T C F X		20	S N A- A A+ A+A A+O A+OA T C F X
	3	S N A- A A+ A+A A+O A+OA T C F X		21	S N A- A A+ A+A A+O A+OA T C F X
	4	S N A- A A+ A+A A+O A+OA T C F X		22	S N A- A A+ A+A A+O A+OA T C F X
	5	S N A- A A+ A+A A+O A+OA T C F X		23	S N A- A A+ A+A A+O A+OA T C F X
	6	S N A- A A+ A+A A+O A+OA T C F X		24	S N A- A A+ A+A A+O A+OA T C F X
	7	S N A- A A+ A+A A+O A+OA T C F X		25	S N A- A A+ A+A A+O A+OA T C F X
	8	S N A- A A+ A+A A+O A+OA T C F X		26	S N A- A A+ A+A A+O A+OA T C F X
	9	S N A- A A+ A+A A+O A+OA T C F X		27	S N A- A A+ A+A A+O A+OA T C F X
	10	S N A- A A+ A+A A+O A+OA T C F X		28	S N A- A A+ A+A A+O A+OA T C F X
	11	S N A- A A+ A+A A+O A+OA T C F X		29	S N A- A A+ A+A A+O A+OA T C F X
	12	S N A- A A+ A+A A+O A+OA T C F X		30	S N A- A A+ A+A A+O A+OA T C F X
	13	S N A- A A+ A+A A+O A+OA T C F X		31	S N A- A A+ A+A A+O A+OA T C F X
	14	S N A- A A+ A+A A+O A+OA T C F X		32	S N A- A A+ A+A A+O A+OA T C F X
	15	S N A- A A+ A+A A+O A+OA T C F X		33	S N A- A A+ A+A A+O A+OA T C F X
	16	S N A- A A+ A+A A+O A+OA T C F X		34	S N A- A A+ A+A A+O A+OA T C F X
	17	S N A- A A+ A+A A+O A+OA T C F X		35	S N A- A A+ A+A A+O A+OA T C F X
	18	S N A- A A+ A+A A+O A+OA T C F X		36	S N A- A A+ A+A A+O A+OA T C F X

## Kansas State University Harvest Audit Program™

### HEPATIC ABNORMALITIES

N= Normal    A= Abscess    +A= Adhesion    +O= Open Abscess

P= Fluke/Parasite    T= Telangiectasis    C= Cirrhosis

FL= Fatty Liver    M= Misc    X= Contamination

### LUNG LESION SCORE

S= Skip    0= Normal    1= < 50% Consolidation (Any Lobe)    2= > 50%

Date \_\_\_\_\_

Location \_\_\_\_\_

Study ID \_\_\_\_\_

Initials \_\_\_\_\_

Carcass #	Seq	Liver	Lung	Carcass #	Seq	Liver	Lung
	1				23		
	2				24		
	3				25		
	4				26		
	5				27		
	6				28		
	7				29		
	8				30		
	9				31		
	10				32		
	11				33		
	12				34		
	13				35		
	14				36		
	15				37		
	16				38		
	17				39		
	18				40		
	19				41		
	20				42		
	21				43		
	22				44		
	23				45		

EE=Entry Error TE: Technical Error

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