Systems Approach to Animal Health – Application to Pneumonia in Beef Calves Prior to Weaning

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Introduction

Livestock production systems are complex adaptive systems. Food production is a system (systems have numerous parts that affect each other); the system is a complex mix of physical, behavioral, biological and economic components with unpredictable outcomes (the parts interact with each other to produce variable outcomes); and the system is adaptive because it changes over time in response to those outcomes. Even within a given food animal commodity (e.g. beef cow-calf, dairy, broiler, catfish) the specific components and outcomes of a production system are highly variable. For example, a beef-cow calf farm in the southeast US may not look or behave like a ranch on the high plains. These differences in the way food animals are produced are due to differences in environmental resources, human resources, and capital –factors which themselves change over time. Within this complexity are biological systems of people, animals, pests, and pathogens –which are also interactive. In spite of the complexity, people make adaptive management decisions hoping to maximize utility (profit, pride, productivity) while minimizing losses due to disease. However, managing complex adaptive systems is not easy because outcomes are difficult to predict.

The science of system dynamics holds promise in helping cattle producers and veterinarians understand how actions and decisions far removed from the immediate problem could be a cause of the problem (Meadows and Wright, 2008). For example, a large regional drought could cause cow-calf producers to decide to wean calves early, seek feedlot pens to house cows, or to depopulate their herds –all of which may have effects on feedlot management and health. Small cow-calf producers may decide not to dehorn, castrate, vaccinate, or deworm calves on the farm because they lack facilities or fail to recognize an economic signal to do so. Decisions made months ago at a farm, possibly hundreds of miles away, may result in increased morbidity and mortality in the feedlot (Duff and Galyean, 2007). Pneumonia (bovine respiratory disease or BRD) in calves prior to weaning is a systems problem paradoxically associated with highly managed herds (Woolums et al., 2013; Woolums et al., 2014).

Bovine respiratory disease in calves prior to weaning

Pneumonia is a leading cause of sickness and death of calves in some cow-calf herds –especially after the first few weeks of life (USDA, 2011). This is perplexing because ranch calves typically live in conditions of little stress and relative isolation. Surveys of beef cattle producers (Woolums et al., 2013) and veterinarians (Woolums et al., 2014) from the northern plains region and southeastern US indicate that pre-weaning BRD is a problem for approximately one out of five cattle producers. Pre-weaning BRD may affect up to 10% of U.S. beef calves (Hanzlicek et al., 2013), resulting in death of 0.6% - 1.4% of all calves (Dutil et al., 1999; Snowder et al., 2005; USDA, 2010). Calves affected with pre-weaning BRD may weigh 17 - 37 pounds less at weaning, compared to calves not affected (Wittum, 1994; Snowder et al., 2005).

The cost of pre-weaning BRD

A risk analysis of the cost of pre-weaning BRD is currently underway (Wang et al, unpublished), but "back of the envelope" calculations considering death loss, morbidity, and treatment costs indicate that BRD in pre-weaned calves might currently cost the US cattle industry $150-200 million annually (Smith et al, unpublished). If so, then that is approximately $5-7 for every beef cow in the country, or $25-35 per cow in affected herds.

Epidemiology of pre-weaning BRD

As with all infectious diseases, the occurrence of BRD is affected by factors of host immunity, presence of specific pathogens, and opportunity for transmission of pathogens between or within herds. It may be useful to think of the various factors that contribute to risk for respiratory disease as component causes. Each factor that contributes to the development of disease is a component cause. Disease is observed when component causes add up to complete a sufficient cause (Rothman, 1976). Without completing a sufficient cause there is no expression of disease. Component causes explain why we might recover *Mannheimia hemolytica* from a deep nasopharyngeal swab of a calf without respiratory disease (other component causes being absent), or why a rancher might observe greater rates of BRD with changes in the weather, whereas another rancher observes BRD following a pasture move (different component causes completing the sufficient cause). Each outbreak of respiratory disease is the result of the completion of a sufficient cause, which might have also included components of viral and bacterial pathogens, a certain state of immunity, or other component causes of respiratory disease in cattle that we fail to understand. Removing one or more component cause prevents the expression of disease. Manageable component causes are called key determinants.

Agents

Although the bacterial pathogens of pneumonia are commonly found in the upper respiratory tract of cattle, the inciting damage is often due to viral infections that may not be present in all cattle herds all of the time. Commonly recognized viral BRD pathogens are bovine herpes virus 1, bovine viral diarrhea virus, and bovine respiratory syncytial virus, but many others, including bovine coronavirus (McNulty et al., 1984; Kapil and Goyal, 1995), are likely to be involved.

Pathogen transmission

In confinement systems the opportunity for pathogen transmission is high because of animal density. But, even in extensive pasture-based systems typical of cow-calf production, opportunities for pathogen transmission may be high because cattle congregate closely around water sources, feedbunks, in shade, and when bothered by flies. Some management practices such as pasture moves and gathering for sorting result in high animal density and greater opportunity for pathogen transmission.

Age associated immunity

Passively acquired maternal immunity is important for protecting calves against respiratory pathogens. However, maternal antibodies wane with time. Approximately every 16 to 20 days after ingestion, the amount of maternal antibodies left in the blood stream is halved, so that by 96 to 120 days of age, a calf retains less than 2 percent of the antibodies it absorbed from colostrum. The immune system is functional but unprimed at birth and prior to 5 to 8 months of age the immune response of calves is weak, slow, and easy to overcome (Cortese, 2009). Therefore, even in the absence of additional stressors, calves 3 to 5 months of age may be particularly susceptible to pneumonia.

Herd immunity

Herd immunity is the protection afforded to susceptible individuals because the majority of the individuals in the population are immune. In herds with a narrow calving window, calves are similar in age and herd immunity is lost in a short span of time as calves approach 90 to 120 days of age. Vaccines to improve immunity against respiratory pathogens have been important for reducing the incidence of BRD in feedlot calves. However, the optimum vaccination protocol to prevent BRD in calves less than 5 months of age remains an important subject of investigation. Weaning, commingling groups, and exposure to severe weather can be powerful stressors that further reduce a calf's ability to resist disease.

Other factors affecting risk for pre-weaning BRD

Health records representing over 9,900 calves from 28 cattle management groups within 7 beef cattle ranches were analyzed to test the effect of calf gender and age of the dam (Smith et al, unpublished). We concluded that the sex of calves affects their risk for BRD (males at greater risk than females). Also, of calves affected with BRD, those calves born to 2 year old dams were more likely to become sick at an earlier age. This is consistent with the knowledge that the male sex of other species has been associated with greater risk for pneumonia (Yamamoto et al., 1991; Gutierrez et al., 2006). The age of the dam may be a correlate of colostrum absorption. Colostrum ingestion may be delayed for calves born to a young dam because of dystocia or poor mothering skills. Also, the young dam's colostrum may not contain as many antibodies, in quantity and range of protection, as older dams (Odde, 1988; Schumann et al., 1990; Odde, 1996).

Prevention of pre-weaning BRD

Management and environment-related risk factors for pre-weaning BRD have been the subject of research (Dutil et al., 1999; Hanzlicek et al., 2013; Woolums et al., 2013; Woolums et al., 2014). Management practices prior to weaning, such as gathering and sorting for artificial insemination, provide opportunity for pathogen introduction and transmission. Activities such as gathering, commingling, sorting, and weaning that increase stress and opportunities for pathogen transmission may have less impact on health if they are completed prior to or after calves are 3 to 5 months of age (Smith, unpublished) or if they were managed to reduce stress and commingling of different groups of calves. Anecdotal evidence indicates that vaccination programs intended to induce adequate acquired immunity in calves prior to 90 days of age have shown some efficacy, but require further study.

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