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Cattle transport: Historical, research, and future perspectives[1]

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ABSTRACT: Transportation and handling is generally regarded as stressful to cattle and includes both physical and psychological stimuli that might be aversive. Historical accounts relate high mortality during the early days of transport and concerns for the welfare of cattle that are similar to those today. Behavior, pathology, and physiology are all used to identify stress in response to transportation. Physiological measures indicate that transport of cattle can result in immune suppression, which can lead to increased susceptibility to disease and might result in increased pathogen shedding. Empirical evidence shows that the neutrophil:lymphocyte ratio is markedly increased when cattle are handled and transported. Agonistic behavior also seems to be decreased by crowding and motion of the truck. Loading, loss of balance, and falling are distressful to cattle. For example, mean heart rates of cattle transported on smooth roads are lower than those of cattle transported on rough country or suburban roads with frequent intersections. Age at transport might also play a role. Young cattle (less than 4 wk old) do not tolerate transport as easily as older cattle, and young cattle do not show a typical physiological stress response as seen in older cattle. This fact, along with mixing practices typical of loads of calves, may make these animals more susceptible to disease. Various remedial strategies have been attempted to decrease cattle response to transportation stress. These include preconditioning, administration of vitamins, vaccines, feeding high-energy diets, and electrolyte therapy. These approaches to managing transport stress have met with little success. Newer methods to reverse the negative physiological responses and to assess behavior during transport are needed. Also research is needed to elucidate the relationship of transport stress to the spread of pathogens of concern to food safety.

Key Words: Animal Welfare, Cattle, Stress, Transport

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Introduction

The majority of beef cattle raised in the United States will undergo transportation at least once in their lifetime. Trucks are the primary form of transport for beef cattle in the United States. Little current information can be found concerning other forms of transport. During the past decade, Warriss (1990), Tarrant (1990), Trunkfield and Broom (1990) and Knowles et al. (1999) conducted scientific reviews of the cattle transport literature. However, the reviews focus on research conducted primarily outside the United States. Tarrant and Grandin (2000) produced a book concerning proper handling and transport of livestock. This article will present an overview of selected literature pertinent to transportation of beef cattle in the U.S. In light of recent refereed reviews, we will not present a comprehensive literature review. Information will be included from research conducted in the United States and pertinent literature from other countries.

Historical Perspectives

The transportation of livestock developed first by ship, then by rail, road, and finally by air. In 1607, the *Susan Constant*, an English ship carrying Jamestown-bound colonists, carried cattle and smaller livestock as provisions (Skaggs, 1986). As the New World developed, supply ships from England carried livestock as regular cargo. Purebred seed stock was imported into the ports of Plymouth and Philadelphia. By 1700, export trade in live cattle and packed meat regularly left the port of Philadelphia bound for the West Indies. Livestock mortality during sea shipment would frequently approach 50% or more, which was attributed to inade-

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quate feed supply, overcrowding, and rough seas (Skaggs, 1986). As colonial expansion headed west, livestock and the meat trade expanded.

By 1848, meat products accounted for nearly 10% of Chicago's exports (Wade, 1987). Concurrently, the U.S. railroad system was developing. During the 1850s, over 2,921 km of railroad track radiated from the center of Chicago to points north, south, east, and west (Wade, 1987). The first shipment of live cattle to Chicago by rail occurred on September 5, 1867 (Kansas Pacific Railway Company, 1874). Twenty carloads of Texas Longhorn cattle left the railhead at Abilene, KS on the Kansas Pacific Railroad destined for the Chicago stockyards. This landmark event forever changed the face of the beef industry. Cattle from western and northwestern Texas were driven to railheads for transport to major feeders, processors, and packers of the High Plains, Great Plains, and Midwest. Cattle trails were carefully mapped to minimize distance and maximize forage to sustain and fatten cattle. Drovers were hired to gather, drive, and concentrate cattle at major buying stations. The best drovers reported en route trail mortality of approximately 3% (Kansas Pacific Railway Company, 1874; Skaggs, 1986). As the railroads expanded, processors multiplied and refrigeration technology developed (the refrigerated rail car was patented in 1867); the need to drive cattle diminished and the land trail systems were rapidly disappearing by 1889 (Skaggs, 1986; Wade 1987).

The improvement of refrigerated transport gave birth to the dressed beef market. The distribution of dressed beef exploded, causing the need to ship live cattle by rail to decrease and to become economically unfeasible. By the early 20th century, railroads dominated the dressed beef market and the commodity trucking industry was in its infancy. Shipping live cattle by truck was economical and offered more flexibility in routing live cattle to auctions, feeders, and processors. Wade (1987) reported early roads composed of wooden planks, known as "plank roads," to facilitate ease of travel. The trucking industry helped to create an interconnected road and rail distribution system throughout the United States and cattle producers vigorously pursued Congress for the expansion and improvement of roadway systems (Skaggs, 1986).

Historical accounts of cattle transport indicate similar goals, concerns, and problems across time. References to efficiency, shrink, mortality, disease, and provision of feed and water were frequent (Skaggs, 1986; Wade, 1987; AHA, 1999). Rail shipments averaged losses of 15% during the latter part of the 19th century (Skaggs, 1986). Animal welfare advocates, the American Humane Association, and ranchers complained about railroad shipping conditions. Among the complaints were schedules that led to overcrowding, inhumane handling, and deficient care of livestock (Skaggs, 1986; AHA, 1999). Congress enacted the "Twenty-Eight Hour Law" in 1906 to set a time limit that livestock could be in rail or ship transit without feed and water. The law, however, did not address transport by road, because the commercial livestock trucking industry had not yet developed.

At present, most beef cattle are transported by road in the United States. The only species of livestock covered by federal regulations that provide for aspects of their welfare during road transport is the horse. Even with the great improvements made to all methods of shipping, transport is still considered one of the most stressful events that cattle will undergo during their lives.

The development of modern scientific methods to assess animal behavior, stress and environmental factors assists in elucidating how these factors contribute to transport stress and their interrelationships. As regulations and codes of practice began to propagate worldwide for the control and oversight of livestock transport, so did the imperative to conduct research. This might explain the abundance of scientific information emanating from the European Union, Australia, and Canada that focuses on animal welfare during transit. In the United States, factors (e.g., disease, mortality, injury, and carcass quality) that produce an observable negative economic impact have been the primary focus of transport research.

Research Perspectives

Many factors are involved in the complex issue that we call "transport stress." Included in this list of factors is pretransport management, noise, vibration, novelty, social regrouping, crowding, climatic factors (temperature, humidity, and gases), restraint, loading and unloading, time of transit, and feed and water deprivation, to name a few. Clearly, an animal's response to transportation is not simple, which also helps to explain the lack of concrete information available regarding transport stress. It is nearly impossible to design a study to identify the contribution of all the factors cited above. We have attempted to make generalizations concerning the effect of transport stress on calves and mature cattle when possible. Variability between studies in transport time, stocking density, group size, weather variables, breed, age, bedding material (for calves), and other factors make this a difficult task. Unfortunately, in many studies these items are not always adequately described in the materials and methods.

We must first define the term "calf," because this is important to the interpretation of studies on cattle transport. Usually cattle under 6 mo of age or between 40 and 400 kg are considered to be calves (Knowles, 1995). We have adopted this definition of "calf" for the current report. Cattle outside these bounds are referred to only as older or mature cattle. An attempt was made to exclude reports specific to dairy cattle transport; this topic will be covered elsewhere. In a few instances, data from dairy cattle were included to supplement the available literature for beef.

Little data currently exist on the number of calves and mature cattle transported in the United States. It has been reported that large numbers of calves are transported from cow-calf areas to feed yards in the Southwest (Cole et al., 1988; Corrier et al., 1990). Forde et al. (1998) reported that only 18 of 50 states record import and export data on cattle. Information is drawn from veterinary inspection certificates and to a lesser extent entry permits in recording states. Import and export profiles developed for Kansas, Texas, Colorado, and Iowa indicate that they received 51% of the reported 1995 imports, and 50% of those imports originate from only nine states. The same four profile states exported more than 50% of their cattle to only three states. According to Forde et al. (1998), nearly half the cattle movement in the United States can be attributed to 13 states plus Mexico; this further substantiates that cattle tend to move toward the center of the United States. Forde et al. (1998) pointed out that the statistics could be misleading because of major cattle states, such as Oklahoma and Nebraska, that have incomplete recording protocols. Knowledge of the movement of cattle is important to understanding how disease is spread geographically and how this contributes to mortality and morbidity.

Morbidity and Mortality

Young calves are especially vulnerable to transport stress. Naive immune systems and lack of exposure to new environments make them more vulnerable than mature cattle; however, this is often not a consideration in decisions to transport calves. Concern for the welfare of cattle during and after transport generally increases with their economic value (Knowles, 1999). Most morbidity and mortality is a result of the number of markets the calves are shipped to, the specifics of each dealer, and weather during transport. Hutchings and Martin (1983) have reported that shipping feedlot calves by truck is associated with less mortality than shipping them by train. Much of the mortality and morbidity literature reviewed focused on calf transport.

The duration of transport per se might not be the most critical factor in transport stress. Sartorelli et al. (1992), using a transport simulator, found that most of the physiological changes associated with transport occur within the first 30 to 60 min, after which changes stabilize (e.g., cortisol, NEFA, and glucose concentrations). Mormede et al. (1982) also showed that there were similar biochemical changes with either short or long transport times. Calf age seems to be the most critical factor in transport-related mortality and morbidity. Knowles et al. (1997) found a negative correlation between age at transport and mortality. Mormede et al. (1982), using multiple regression, found that duration of journey had a significant influence on morbidity but the measurements that change with transport are highly correlated with calf age, again indicating that age at transport is a key factor.

Time of day (day vs night) may be an important variable in how much rest, and thus stress, calves experience during and after transport (Cole et al., 1988). Compared with calves transported 24 h or control (feed-deprived) calves, those transported 12 h and returned to pens at night had higher mortality and morbidity after arrival (Cole et al., 1988). Knowles et al. (1997) also reported that following a 19-h transport, young calves did not rest well during the night following transport.

Shipping fever and diarrhea are problems in transported calves and a significant component of calf morbidity and mortality. In a survey by Staples and Haugse (1974), pneumonia was identified as the greatest cause of death in transported calves. Moreover, calves less than 2 wk of age had higher rates of mortality and morbidity. *Pasteurella haemolytica* is generally considered to be the primary pathogen in shipping fever. Frank and Smith (1983) found that after arrival at a feedlot, *Pasteurella haemolytica* was increased in nasal swabs of calves that were sent to auction barns and transported to feedlots.

Transport mortality in mature beef cattle is reported as low (Knowles, 1999). Tarrant et al. (1992) found that high stocking densities (550 kg/m^2) decreased the welfare of steers on a 24-h journey and that plasma cortisol and glucose remained elevated after transport. No deaths were reported. Warriss et al. (1995) transported steers for 5, 10, or 15 h at distances of 286, 530, and 738 km, respectively. Warriss et al. (1995) concluded that when conditions are good, 15-h transport is not detrimental to cattle welfare. The authors noted differences in physiological responses to transport between breed types used in the study. Hereford × Friesan cattle had lower creatine kinase (**CK**) values, a measure of muscle fatigue, than did “continentals.” Sex might also contribute to ability to withstand transport. For example, Lambooy and Hulsegge (1988) found that heifers were more fatigued at the end of an 18-h journey. Similar to the previous studies, no transport mortality was reported. Previous literature reviews confirm low morbidity and mortality in finished and mature cattle transported to slaughter; however, actual data on the number of downed and dead cattle on arrival at U.S. processing plants are lacking.

Physiological Response to Transport

Because transportation represents a source of stress for cattle, most studies indicate an increased body temperature, increased heart and respiration rates, and activation of the hypothalamic-pituitary-adrenal axis (**HPA**). Activation of the HPA results in increased concentrations of glucose, cortisol, and NEFA in the blood. Very young calves (< 4 wk of age) might not always react to transport with a large HPA response (Mormede et al., 1982). Other reports also have failed to find an increase in cortisol following transport in older calves (Cole et al., 1988), although the majority of studies with calves older than 8 wk have shown an increase in corticosteroids following transport (Crookshank et al., 1979; Simensen et al., 1980; Kent and Ewbank, 1983, 1986a,b). Reports of changes in plasma glucose are variable, with some reports of increases in plasma glucose concentrations (Kent and Ewbank, 1983 and 1986a,b) and others reporting no change (Locatelli et al., 1989, Sartorelli et al., 1992; Knowles et al., 1999). Variation among studies is likely a result of the use of a transport simulator instead of actual transportation and sampling and transport times.

Older cattle tend to stand during transport and muscle fatigue becomes a factor. Muscle enzymes, such as CK, are usually increased in blood (Knowles et al., 1999). In young calves, which spend more time lying down, the increase in CK is not generally observed (Kent and Ewbank, 1986a,b). Other changes in blood plasma include increases in serum chloride and hemoglobin concentrations but decreases in blood pH (resulting in part from increases in FFA). Urine sodium might also be elevated following transport (Knowles et al., 1999). Measurements reflective of dehydration also have been reported, including increased packed cell volume (Kent and Ewbank, 1983; Locatelli et al., 1989) and serum protein (Kent and Ewbank, 1983), although Kent and Ewbank (1986a,b) did not find increased packed cell volume or serum protein concentrations in calves less than 3 mo old that were subjected to transport.

In older cattle, cortisol concentrations increased in response to loading, unloading, and during the first portion of a journey (Wariss et al 1995; Grandin 1997; Knowles, 1999). During transport of repeated or long duration, cortisol concentrations might decrease as a result of habituation (Warriss et al. 1995; Lay et al. 1996). Creatine kinase tends to increase with duration of journey, as do albumin, total plasma proteins, and osmolality. Free fatty acids, urea, and β-hydroxybutyrate also increase. In the case of long-distance transport, recovery to pretransport levels is slow because of the disruption of eating cycles and water deprivation. Recovery can take as long as 5 d after transport (Warriss et al., 1995).

Different combinations of stress produce mixed physiological responses. For example, Mitchell et al. (1988) assessed the blood characteristics of unstressed cattle compared with cattle subjected to combinations of handling, transport, and slaughter. They found that handling produced significantly higher triiodothyronine (**T_3**), cortisol, lipid, and lactate concentrations than those in unhandled cattle, whereas transport produced higher catecholamines and lactate but lower cortisol concentrations. Lipid, glucose, and T_3 concentrations did not differ between handled and transported cattle. Transported and slaughtered cattle (blood collected after stunning) produced similar concentrations of T_3, cortisol, and lipids, but slaughter produced significantly higher catecholamines, glucose, and lactate. Mitchell et al. (1988) provided important baseline and stress response information. They concluded that two phases of physiological response to stress exist. The first phase involves a stage of "perception of events." Poor handling practices (fear), novelty, and anxiety are implicated in producing negative responses that can cause the activation of the HPA-adrenal cortical complex (Grandin, 1997; Jacobsen and Cook, 1998). The second phase involves a sympathetic adrenal medulla response that can occur when neurogenic (transport) or massive trauma (stunning) flood the system. Other cattle studies measuring blood characteristics relative to stress tend to support these conclusions in mature cattle (Kent and Ewbank 1983, 1986a,b).

Immunological Response to Transport

There are more reports on the effects of transport on the immune response in calves than for any other topic we reviewed. This is primarily a result of the interest in calf health and the development of effective ways of decreasing transport stress.

In general, the calf's immune system responds to transport stress by increasing the number of total white blood cells (**WBC**) and specific types of WBC (neutrophils, eosinophils, and mononuclear cells) in circulation (Kent and Ewbank, 1986a,b; Murata et al., 1987). Lymphocyte numbers are decreased (Kent and Ewbank, 1986a,b; Murata and Hirose, 1991), which, along with increasing numbers of neutrophils, increases a particular measure of stress, the neutrophil:lymphocyte ratio (**N:L**). Murata et al. (1987) found a decrease in T-lymphocyte numbers of 4- to 6-mo-old calves transported 4 h but no change in the number of B lymphocytes. Kent and Ewbank (1986b) found, in very young calves (1 to 3 wk old), that changes in WBC numbers occurred after approximately a 6-h transport. In calves transported for 18 h, WBC were back to baseline levels near the end of the trip, although they did observe an increase in neutrophils and decrease in lymphocytes.

Several studies have determined the functional capacity of the immune response using in vitro tests following transport. Murata et al. (1985, 1987) showed an increase in the oxidative capacity of neutrophils with a nitroblue tetrazolium (**NBT**) reduction assay. Lymphocyte blastogenesis in response to mitogen stimulation may be suppressed following transport (Kelley et al., 1981; Murata et al., 1987; Murata and Hirose, 1990), although there are several reports that blastogenesis might be enhanced following transport (Murata et al, 1985; Murata and Hirose, 1991). Again, variation in calf age, duration of transport, and time when samples were collected adds to the difficulty in interpretation of such results.

Along with the report that numbers of B lymphocytes do not change, concentrations of immunoglobulins in blood have been shown to be unaffected by transport stress (Kelley et al., 1981; Mormede et al., 1982). In light of the age of research data on immune function following transport, this is an area that would benefit from additional research. Tools are available now to look at specific populations of cells and their function, specifically cells that might play a protective role against pathogens at the epithelial surfaces (lungs and gastrointestinal system).

It has generally been thought that activation of the HPA axis is responsible for suppression of the immune response following stress. In a series of studies, Murata (1989), Murata and Hirose (1991), and Murata and Miyamoto (1993) showed that sera from calves that were transported 4 h contained a suppressive factor when added to lymphocyte cultures in the mitogen-stimulated blastogenesis assay. This research indicated for the first time that changes in serum factors might be more important in immune suppression than changes in white blood cell function. This “transient serum immunosuppressive factor(s)” (Murata, 1989) was subsequently found to have 33-kDa and 20-kDa fractions, which probably correspond to the α- and β-subunits of the acute phase protein haptoglobin (Murata and Miyamoto, 1993). Murata and Miyamoto (1993) found a correlation ($r = 0.57$) between haptoglobin concentrations and lymphocyte suppressive activity in sera. Other acute phase proteins such as α_1-acid glycoprotein (Murata and Miyamoto, 1993) and fibrinogen (Phillips, 1984) have not been shown to increase following transport.

We found fewer studies that reported immune measurements for older cattle subjected to transport stress. Of the studies found, most involved small numbers of animals. Tarrant et al. (1992) used Friesian steers ($n = 96$) subjected to transport for 24 h to assess changes in blood measurements before and after transport. Compared with pretransport values, Tarrant et al. (1992) reported increases in total WBC (23%) and neutrophils (68%) and decreases in eosinophils (65%), lymphocytes (28%), and monocytes (2.6%). These data indicate that older cattle have immune responses to transport, but perhaps older cattle are not as susceptible to generalized immunosuppression as young calves.

Behavioral Response to Transport

At the early stages of transport, active behaviors and social interactions are usually high. Knowles et al. (1997) reported that calves transported 19 h spent more of the first 10 h of transport standing (64% in summer and 90% in winter) compared with the last 9 h (14% in summer and 25% in winter). The high rate of lying in these young calves is probably a result of the stocking density used in the particular studies (122 to 129 kg/m^2) that allowed the calves to lie down comfortably.

In a study by Kent and Ewbank (1986b), calves less than 4 wk of age spent 33 to 36% of their time lying down. In this same group of calves, those transported for 6 h spent 27.3% of their total time ruminating while standing; for calves transported 18 h this value was 36.4%. The same study was repeated with 3-mo-old calves (Kent and Ewbank, 1986a). These older calves spent between 13 and 42% of the time lying. Three-month-old calves spent less time ruminating than did younger calves, suggesting that transport might be more stressful to older calves. The same researchers also looked at transport in 6-mo-old calves (Kent and Ewbank, 1983). Older calves defecated and urinated more than younger calves and also salivated more. Older calves spent less time lying (5.7%) and ruminating (1.4%) during transport than younger calves.

The orientation of cattle to direction of travel during transport tends to be perpendicular or parallel. At medium or low stocking densities, cattle will demonstrate a preference for standing perpendicular rather than parallel to the direction of motion (Tarrant et al., 1992). Cattle tend not to lie down during transport, but they can arrive fatigued and exhibit increased lying behavior after off-loading at the processing facility (Kenny and Tarrant, 1987a,b; Tarrant et al., 1989; Tarrant et al., 1992). Changes in balance were primarily responsible for shifting, struggling, and falls during transit. Loss of balance can be attributed to driver behavior such as braking, stopping, and cornering, and falling was less evident at high vs low stocking densities (Tarrant et al. 1989, 1992). Investigative behavior tends to decrease after the first 4 h in transit and few or no aggressive or sexual behaviors are exhibited at various stocking densities (Tarrant et al., 1989, 1992).

Stocking density for transported calves is an area that lacks solid research data. In 1991, the Farm Animal Welfare Council (FAWC) proposed a space guideline of $0.021\mathrm{BW}^{0.67}$ of the animal (FAWC, 1991). Randall (1993) proposed an area of $0.01\ \mathrm{BW}^{0.78}$. These values might not represent optimum densities for shipping calves, because they tend to have smaller individual spaces and might prefer to lie down during transport (especially very young calves). Studies have indicated that for certain variables (e.g., shrink and shipping fever) the compartment of the trailer in which calves are transported does not affect health or performance (Camp et al., 1981).

Many reports reviewed did not give information on critical factors such as stocking density or type of bedding material provided. Stocking density is clearly an area that requires additional research.

Effect of Transport on Preslaughter Food Safety and Carcass Quality

Although it seems that there is a generalized immunosuppressive response of calves to transport and an increase in mortality and morbidity, the consequences of transport on the animal’s ability to respond to foodborne pathogens has not been adequately studied. In one report, Wray et al. (1991) indicated that transport vehicles might be an important link in the spread of *Salmonella* among calves. *Salmonella* was isolated from 20.6% of vehicles before cleaning and 6.5% of all vehicles after cleaning. The most prevalent serotype identified was *S. typhimurium*.

In a study of 3- to 5-mo-old mixed-breed feeder calves by Corrier et al. (1990), *Salmonella* was not recovered in fecal samples from animals while at their farm of origin or at an auction market. After transport from Tennessee to Texas feedyards, through 30 d at the feedyard, 16 of 200 calves were fecal culture-positive for *Salmonella*.

In finished cattle, stress factors can greatly affect meat quality. Stress-induced dark cutters, bruising, and blood spots have been well substantiated in the meat science literature (Grandin, 1997). The decrease in economic value of carcasses can be devastating. Bruising has been a major concern to the U.S. beef cattle industry and has been estimated to account for $114,452,000 in annual economic losses (Boleman et al., 1998). Research supports that more bruising occurs at the handling phase at auctions or at the processors (McCausland and Miller, 1982; McNally and Wariss, 1996, 1997; Hoffman et al., 1998) as opposed to during transit. Hoffman et al. (1998) reported that mature cows subjected to first-point testing for brucellosis at auctions and transported for long distances produced carcasses with more severe bruises and a greater number of bruises than ranch-derived cows or cows not subjected to first-point testing. Sex of cattle might influence whether bruising occurs during transport. Yeh et al. (1978) reported increased bruising in cows as opposed to bulls as transport time increased from 3 to 10 d of transport. No differences in bruising were found within mixed-sex groups. Time in transit per se has not been reported to increase bruising (McNally and Warriss, 1997).

As expected, horned cattle experience more bruising in transit than polled or tipped cattle (Ramsay et al., 1976). Feed deprivation before transport might increase the incidence of bruising. Dodt et al. (1979) reported greater amounts of bruised trim in feed-deprived bulls as opposed to fed bulls after transport. There was no relationship found to duration of time bulls were feed-deprived.

Remediation of Transport Stress

Preventative measures used to condition cattle for transport have largely focused on calves. Weight is generally affected during the first 24 h of transport (body weight losses of 3 to 11% are typical; Warris, 1990). The use of oral electrolytes has been somewhat effective in decreasing this transport-related weight loss (Schaefer et al., 1997). Knowles et al. (1997) concluded that midjourney supplementation with electrolytes decreases dehydration, but allowing access to cold water might be detrimental to calves because it altered their electrolyte balance in a negative way. Other attempts, such as the use of vitamins, have not decreased weight loss (Jubb et al., 1993). Weight loss of calves after arrival at a commercial feedlot can decrease the ADG and gain:feed ratio for at least the first 28 d (Cole et. al., 1988).

In one report, Jacobson and Cook (1998) attempted to partition transport stress into physical and psychological compartments. Their hypothesis was that if calves could be transported without anxiety (psychological stress), it would be easier to assess the effect of transport on calf welfare. Anxiety was pharmacologically blocked with the use of a mixture of cholecystokinin (**CCK**) antagonists that do not sedate the animal. Use of these CCK antagonists did not decrease heart rate during transport in 6-wk-old calves, although some question as to the effective dose of CCK antagonists used was evident in this study.

Preconditioning (vaccination, castration, dehorning, and weaning programs) has been developed to increase health of calves sent to feedlots and decrease the effect of transport stress. The use of such preconditioning strategies has been questionable. Preconditioning was not found to reduce weight loss following transport in several studies (Cole, 1985; Pritchard and Mendez, 1990). However, backgrounding (with vaccinations) for 30 to 45 d after weaning seems to be effective for reducing mortality.

Calves (10-d-old) supplemented with 20 mg/kg of vitamin E (tocopheryl-acetate) before transport showed no significant improvement in immune response (total WBC, differential leukocyte counts, T lymphocyte subpopulations, phagocytic activity, and leukocyte migration) compared with control calves. Remediation programs could play an important role in ameliorating the effects of transport stress; however, identification of effective strategies is still needed and merits additional research.

Future Perspectives

As indicated by this overview, comparatively little research has been conducted on the welfare of transported feeder and stocker calves in the United States, even though it is a well-known part of beef cattle production. Questions remain as to the appropriate stocking density for calves both in the United States and Europe. In general, it can be said that transport causes stress beyond what is caused by feed deprivation alone and that most stress is incurred during the early phases of transport. Poor handling before and after transport can exacerbate these effects.

Management before and after transport, nutrition (Phillips et al., 1982; Cole et al., 1986; Cole and Hutcheson, 1990; Schrama et al., 1996a,b) and genetics (Zavy et al., 1992) play a large role in how calves respond to transport stress. Unfortunately, a systematic approach to the study of the effects of transport stress on calves is still lacking, particularly for truck transportation in the United States. Neither is there a validated model system for evaluating the components of transportation stress. Using pregnant cows, Lay et al. (1996) attempted to model transport stress response by using ACTH challenge but failed to reproduce the same physiological response as actual transport. Such a model system would allow hypothesis-driven research to be conducted on how transportation affects behavior, physiology, health, and shedding of pathogens relevant to the question of preslaughter food safety. In addition, such a model would allow the testing of methods to remediate transport stress before they are applied in production systems.

Calves less than 4 wk old do not seem to mount a typical HPA response to the stress of transportation. The data available seem to indicate that morbidity and mortality are high following transport of young calves, indicating that they are extremely sensitive to the stress associated with transport.

Other factors that contribute to the transport experience such as truck design, routes of travel, driver training, and en route driver and cattle behavior also are important. Little is published from such research in the United States and results might be held as proprietary information. Newer computer tracking and recording technologies could afford more advanced insight into how cattle, truck, and driver interrelate during long- and short-distance transport.

Implications

The United States has fallen behind in the investigation of transportation of beef cattle and how such transport affects welfare. We risk accepting standards derived from research outside of the United States when regulatory oversight eventually becomes a reality for livestock transportation.

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