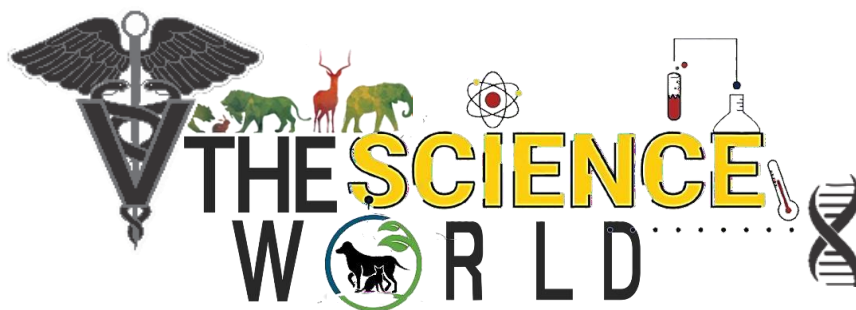




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Transportation Stress in Livestock: A Review of Stressors, Physiological Effects, and Nutritional Strategies for Amelioration

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Abstract

Transportation is an essential component of livestock production and marketing, but it can expose animals to physical, physiological and psychological stress. Handling procedures, environmental conditions, vehicle vibration, overcrowding, restricted access to feed and water, and unfamiliar surroundings contribute to transportation-related challenges. These stressors can trigger hormonal and metabolic responses, oxidative stress, immune suppression, digestive disturbances and behavioural changes, ultimately affecting animal welfare, health and productivity. Nutritional strategies offer potential support for managing these effects through electrolyte supplementation and rehydration, antioxidant nutrients such as vitamins C and E and selenium, energy-dense diets, probiotics, prebiotics, yeast derivatives and selected immune-modulating supplements. Herbal adaptogens have also been explored for their potential role in stress resilience. However, the effectiveness of these interventions depends on animal species, physiological status, journey conditions and appropriate supplementation. Nutritional measures should complement, rather than replace, proper transport planning, adequate space allowance, ventilation, careful handling and access to water. Integrating sound nutritional and management practices can improve livestock welfare and support recovery following transportation.

Key Words: Livestock transportation; Transportation stress; Animal welfare; Oxidative stress; Immune suppression; Electrolyte supplementation; Antioxidants; Gut health; Nutritional management; Stress mitigation

2916



Introduction

Transportation of livestock involves grouping and loading of animals at their place of origin, confining them to a moving or stable vehicle, unloading, and eventually lairage or penning at their ultimate destination. Transportation stress occurs when animals experience physical, physiological, and psychological challenges during transit. Stress may be a hypothalamic-adreno-cortical process, which is related to neurogenic stress such as noise and transport (Mitchell *et al.*, 1988). Transportation stress has been documented to cause a rise in plasma glucose concentrations due to an attempt to compensate for energy loss during transportation, mobilization of glucose from glycogen in the liver and muscles into the systemic circulation, or reduction of glycogen reserves from the skeletal muscles (Eniolorunda *et al.*, 2009). These challenges result in behavioural changes, physiological disruptions, and immunosuppression, adversely affecting animal health, welfare, and productivity.

Causes of Transportation Stress

Transportation stress arises from several interconnected factors:

1. **Handling Stress:** Improper handling during loading and unloading causes fear and physical injuries. Studies have shown that rough handling increases cortisol levels, leading to acute stress responses (Grandin, 2019). Proper training of personnel and the use of low-stress handling techniques are critical to minimizing this factor.
2. **Environmental Factors:**
 - a) **Temperature fluctuations:** Heat or cold stress during transit, especially in poorly ventilated vehicles, exacerbates discomfort. Research indicates that cattle transported at high temperatures experience a significant rise in body temperature and respiratory rates, leading to heat stress (Schwartzkopf-Genswein *et al.*, 2007).
 - b) **Humidity: High relative humidity reduces the efficiency of evaporative cooling and can aggravate heat stress in livestock. Environmental factors such as temperature, relative humidity, wind speed, and solar radiation collectively influence the severity of heat stress, with temperature–humidity interactions commonly assessed using the temperature-humidity index (THI) (Mader *et al.*, 2006).**
3. **Physical Stress:** Vibration, noise, and motion lead to discomfort and fatigue. A study on broiler chickens revealed increased levels of corticosterone due to prolonged exposure to vehicle vibrations.
4. **Dehydration and Starvation:** Limited access to water and feed during transport can cause dehydration, energy deficits, and electrolyte imbalances. Evidence shows that withholding



water for more than 12 hours increases plasma osmolality and negatively affects animal welfare (Knowles *et al.*, 1999).

5. **Crowding and Confinement:** Overcrowding increases the risk of injuries and respiratory issues due to poor air quality. Research indicates that stocking densities exceeding optimal levels lead to elevated ammonia concentrations, exacerbating respiratory conditions.

Space Allowances for Road and Rail Transport of Livestock as per BIS 2007

a) Transport by road or rail space allowance for cattle

Class	Weight (kg)	Mean Cattle Dimensions (m ²) Width x Length	Space Required (m ²) Unhorned	Space Required (m ²) Horned
Calves	Up to 50	0.27 × 1	0.28	0.28
	50-100	0.46 × 1.32	0.56	0.56
	100-200	0.46 × 1.33	0.62	0.73
Cattle/Bufaloes (Young/Adult)	200-300	0.56 × 1.52	0.86	0.96
	300-400	0.64 × 1.65	1.06	1.2
	More than 400	-	>1.27 to 1.73	>1.59 to 2

b) Transport by road or rail space allowance for sheep and goats

Class	Weight (kg)	Mean Woollen Sheep/Goat Dimensions (m ²) Width x Length	Space Required (m ²) Woollen	Space Required (m ²) Shorn
Lambs	Up to 15	0.24 × 0.6	0.15	0.15
	16-20	0.25 × 0.7	0.17	0.16
	21-25	0.26 × 0.74	0.19	0.16
	26-30	-	0.22	0.22
Sheep/goats	31-40	-	0.25	0.24
(Adults)	41-55	0.35 × 0.91	0.35	0.35
	More than 55	-	>0.40	>0.40

6. **Psychological Stress:** Fear and unfamiliar environments elevate cortisol levels, suppressing immune functions. Behavioural studies confirm increased vocalizations and agitation during the first few hours of transport as indicators of distress (Tarrant & Grandin, 2000).

Physiological and Health Effects of Transportation Stress

1. **Oxidative Stress:** Stress during transport causes an elevation in cortisol and catecholamine levels, which enhances the production of reactive oxygen species (ROS). ROS lead to oxidative damage to cellular components like lipids, proteins, and DNA. This imbalance between pro-oxidants and antioxidants results in oxidative stress, which can:



- a) Impair cellular functions.
 - b) Weaken antioxidant defences.
 - c) Increase the risk of metabolic disorders.
2. Immune Suppression: Transportation stress impairs the immune system primarily due to elevated glucocorticoids (e.g., cortisol). These hormones:
- a) Suppress the proliferation and activity of immune cells such as lymphocytes.
 - b) Reduce antibody production.
 - c) Increase vulnerability to infections, particularly respiratory diseases like pneumonia and shipping fever in cattle.
 - d) In a study conducted in Holstein- Friesian bulls lymphocytes were taken after transportation and were cultured, and stimulated with concanavalin A, there was decrease in IFN γ production which suggested that reduction in the immune function (Gupta *et al.*, 2007).
 - e) After transportation, immunosuppressant predisposes calves to acquire bovine respiratory disease (BRD), which usually occurs during the first 45 days of arrival and is associated with 65-80% morbidity and 35-55% mortality.
3. Digestive Disruption: Transportation affects gastrointestinal health in multiple ways:
- a) Altered Motility: Stress can reduce gut motility, leading to constipation or hyper motility, which causes diarrhoea.
 - b) Microbiota Imbalance: Stress disrupts gut microbiota, reducing beneficial bacteria while promoting pathogenic growth.
 - c) Nutrient Absorption: Impaired gut function affects nutrient absorption, contributing to energy deficits.
4. Metabolic Imbalances: Stress during transportation often leads to reduced feed and water intake, causing:
- a) Dehydration: Loss of fluids and electrolytes due to heat stress and reduced water intake.
 - b) Energy Deficits: Decreased feed intake results in hypoglycaemia, fatigue, and weight loss.
 - c) Electrolyte Imbalances: Dehydration alters sodium, potassium, and chloride levels, affecting cellular and metabolic functions.
5. Behavioural Changes: Stress is evident in altered animal behaviour, including:
- a) Restlessness and Vocalizations: Animals may pace or vocalize excessively due to discomfort or fear.



- b) **Reduced Exploratory Behaviour:** Stressed animals exhibit lethargy or lack of interest in their environment.
- c) **Aggression or Withdrawal:** In some cases, animals may become aggressive or withdrawn, indicating psychological distress.

Nutritional Strategies for Ameliorating Transportation Stress in Livestock

Transportation stress significantly affects animal physiology, resulting in oxidative stress, dehydration, gut health disturbances, and immune suppression. Nutritional interventions offer targeted solutions to mitigate these effects. Below is a detailed review of nutritional strategies based on scientific findings.

1. Dehydration Management: Electrolytes and Rehydration Solutions

- **Importance:** Transportation often limits water availability, leading to dehydration and electrolyte imbalances.
- **Intervention:** Supplementation with electrolytes like sodium chloride, potassium chloride, and magnesium sulphate in drinking water or feeds can restore osmotic balance and improve hydration.
- **Scientific Findings:**
 - Electrolyte supplementation significantly reduces dehydration markers and maintains plasma osmolality during transit in poultry and cattle.
 - Oral rehydration solutions (ORS) with glucose enhance water absorption by activating sodium-glucose cotransporters in the gut.
 - The significance of balancing dietary ion charges and electrolytes to improve efficiency has been recognized for some years in dairy cattle (Beatty *et al.*, 2007)
- **Mechanism:**
 - Electrolytes facilitate water absorption through sodium-glucose cotransport in the intestinal tract.
 - Magnesium prevents muscle cramps and aids in stress resilience by maintaining nerve and muscle function.

2. Antioxidant Supplementation: Transportation stress induces oxidative stress by increasing reactive oxygen species (ROS), damaging proteins, lipids, and DNA. Antioxidants neutralize ROS and protect cellular integrity.

a) **Vitamin E:**

- A lipid-soluble antioxidant that protects cell membranes.
- Many researches in transported pigs showed that dietary Vitamin E reduced lipid peroxidation and improved recovery post-transport.



b) Vitamin C:

- A water-soluble antioxidant that reduces cortisol levels and enhances immune response.
- Vitamin C reduces the gradual levels of radicals that arise as a result of stress during transportation (Chambial *et al.*, 2013).
- Poultry supplemented with Vitamin C (250-300 mg/kg feed) demonstrated lower oxidative stress markers and better feed conversion post-transport.

c) Selenium:

- Works synergistically with Vitamin E as a cofactor for glutathione peroxidase.
- Studies in goats showed that selenium supplementation reduced oxidative stress during transportation.

d) Polyphenols:

- Natural antioxidants like green tea extract and resveratrol reduce oxidative damage during stress events.

3. High-Energy Diets: Energy loss or hypoglycemia is one of the typical effects of animal transportation and handling. Energy deficits during transportation occur due to limited feed intake and increased energy expenditure.

Carbohydrate and Fat Supplementation

- Feeding energy-dense diets before transport increased glycogen stores in cattle, preventing hypoglycaemia during transit.
- Nutritional supplements in the form of pre-transport energy result in hot carcass weight gains as cattle are shipped to market (Grumpelt *et al.*, 2015).
- Rumen-protected fats provided sustained energy in ruminants without increasing metabolic heat, critical for hot climates during transportation.
- Mechanism: High-energy diets compensate for reduced intake by providing a concentrated source of calories. Fats have a lower heat increment than carbohydrates, making them ideal under heat-stress conditions.

4. Gut Health Support

Transportation stress disrupts gut microbiota, increasing gut permeability ("leaky gut") and risk of diarrhoea.

a) Probiotics:

- *Lactobacillus acidophilus* and *Bifidobacterium bifidum* stabilize gut flora and improve nutrient absorption during stress.



- Research on broilers demonstrated that probiotics reduced gut inflammation and enhanced post-transport weight gain.
- Probiotics improved feed conversion ratios and gut health in transported poultry.

b) Prebiotics:

- Prebiotics, like mannan-oligosaccharides (MOS), support beneficial bacteria and gut integrity.
- Studies in pigs showed that MOS supplementation improved gut health during transit.
- MOS supplementation reduced intestinal permeability and inflammation in transported calves.

c) Yeast Derivatives:

- Live yeast (*Saccharomyces cerevisiae*) enhances rumen microbial activity and digestion in cattle.
- Supplementation reduced cortisol levels and prevented acidosis during long transport.

5. Immune Modulators

Transport stress suppresses the immune system, increasing susceptibility to infections like respiratory diseases.

a) Zinc:

- Improves barrier function by stabilizing tight junctions in the gut epithelium and enhances immune cell activity.
- Supplementation of 100 mg/kg of organic zinc improved recovery from stress in transported cattle.

b) Selenium:

- Protects against immune suppression by enhancing leukocyte function.
- Some research in sheep showed that selenium-enriched diets reduced inflammatory markers post-transport.

c) Omega-3 Fatty Acids:

- Modulate inflammatory responses by producing anti-inflammatory eicosanoids.
- Fish oil supplementation in pigs reduced systemic inflammation during transportation.

6. Adaptogens and Herbal Supplements: Adaptogens are natural compounds that enhance stress resistance by modulating the hypothalamic-pituitary-adrenal (HPA) axis.

a) Ashwagandha (*Withania somnifera*):

- Reduces cortisol levels and oxidative stress.
- Studies in poultry demonstrated improved weight gain and lower stress biomarkers when ashwagandha was supplemented at 2% of the diet.



b) **Rhodiola rosea:**

- Enhances endurance and reduces fatigue.
- Research in swine found reduced stress indicators post-transport with Rhodiola supplementation.

7. **Feeding Practices:** Strategic feeding practices before, during, and after transport help mitigate stress.

- a) **Pre-Transport Diets:** Providing high-energy, easily digestible diets before transport builds energy reserves.
- b) **During Transport:** Access to water and small, frequent feedings reduce dehydration and digestive disturbances.
- c) **Post-Transport Recovery:** Immediate rehydration with electrolytes and glucose accelerates recovery.

Conclusion

Transportation stress can significantly impair livestock health and productivity. While long-term animal transport is more likely to compromise animal welfare than shorter journeys, it is important to note that it is not the length of the journey but the related negative factors that are the cause of the welfare problems that have been identified and stress on the animals. Nutritional strategies for transportation stress focus on mitigating dehydration, oxidative stress, energy deficits, and immune suppression. Tailored interventions, such as electrolyte supplementation, antioxidants, probiotics, and adaptogens, have been scientifically proven to enhance animal resilience and performance during and after transport. Combining these strategies with proper handling and management practices ensures better welfare and productivity.

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