LIVE.104B
Use of electrolytes to alleviate stress: Desk Top Study

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EXECUTIVE SUMMARY

The joint Meat and Livestock Australia (MLA)/LiveCorp project LIVE.104, "Desk Top Study" is the first stage of a project that aims to deliver recommendations to industry on the best use of electrolytes for alleviating stress in cattle and sheep on board livestock vessels. The desk top study is a review of the scientific literature and live export industry practices to investigate the use and potential benefits of electrolyte supplements during shipping. It identifies sea transport stress factors and describes the physiological and clinical effects of these in cattle and sheep and considers the benefits of electrolyte supplementation in treating these clinical syndromes. Most findings have been drawn from land-based studies and current knowledge of veterinary medicine due to the lack of specific shipboard data.

Recommendations for research are made to enable the development of robust and effective guidelines on the best use of electrolytes. It is proposed that field trials and development of best practice guidelines be carried out in the second stage of this project along with the development of a communication strategy to maximise uptake of the guidelines by industry.

The main functions of electrolytes are to satisfy dietary nutrient requirements and maintain the acid-base balance (neutral pH) of the body. Hence, electrolyte treatments or supplements aim to replenish lost electrolytes and/or correct an acid-base imbalance and there are a number of products currently available in Australia that can do this during the live export of cattle and sheep. To be effective, electrolytes need to alleviate heat and nutritional stress that occurs during live export. Correcting the physiological imbalances that occur as a result of these stresses is the key to the best use of electrolytes.

There is insufficient data to draw any conclusions on the cost-benefits of electrolytes during shipping or to make any recommendations on their best use. In order to determine if there is a cost-benefit of providing electrolytes to cattle and sheep during shipping, two questions need to be answered:

1. What electrolyte formulation is required to alleviate heat and fasting stress during shipping?
2. What are the benefits of providing the correct electrolyte supplement during shipping?

The actual physiological state of cattle and sheep during shipping has not been confirmed. The literature suggests that for cattle, heat stress encountered during shipping will result in metabolic acidosis, while experience suggests that respiratory alkalosis is a significant problem. For sheep, research findings suggest that glucose supplementation may be required to treat inanition, the main cause of deaths during shipping. The current use of electrolytes by the industry is not consistent with these findings.

Land-based studies on the benefits of electrolytes are inconclusive and do not allow any conclusions to be drawn. A general pattern of electrolyte use and industry views on the benefits of electrolytes cannot be determined due to the differences in opinion that exist in the industry. Hence, we recommend that specific research under commercial conditions be conducted into the benefits and costs of electrolyte supplements during shipping. Following are the key findings of this review and recommendations for research to provide the necessary information for guidelines on the best use of electrolytes during shipping to be developed.

KEY FINDINGS

Electrolytes and electrolyte products

- ☑ Electrolytes are sodium, potassium, magnesium, calcium, chloride and bicarbonate.
- ☑ Electrolytes satisfy dietary nutrient requirements and maintain the acid-base balance of the body.
- ☑ Sodium, potassium, chloride and bicarbonate have the greatest effect on acid-base balance.
- ☑ Electrolyte supplements replenish lost electrolytes and/or correct an acid-base imbalance.
- ☑ Electrolyte supplements suitable for use in cattle and sheep on livestock vessels are available in Australia and include:
    - DEB9®;
    - Selectolyte®;
    - Glucotrans®;
    - Topstock Electrolytes;
    - Solulyte Concentrate®; and
    - Selectrolyte®.

Sea transport stress factors and their effects

- ☑ The main causes of stress in cattle and sheep during sea transport are:
    - Heat;
    - Poor ventilation; and
    - Fasting.
- ☑ Heat, poor ventilation and nutritional stress result in:
    - Hyperthermia (heat stress);
    - Pneumonia (respiratory distress);
    - Starvation; and
    - Dehydration.
- ☑ The actual physiological state of cattle and sheep during sea transport is not confirmed.
- ☑ Heat and nutritional stress during shipping have a significant effect on livestock and meat quality. They can lead to:
    - metabolic disorders, particularly:
        - dehydration;
        - acidosis and/or alkalosis;
        - low blood glucose;
        - ketosis; and
        - fatty liver;
    - liveweight loss; and
    - poor meat quality.
- ☑ To be effective, electrolyte supplements used during shipping may need to do one or more of the following:
    - Correct electrolyte deficiencies;
    - Correct acidosis;
    - Correct alkalosis; and
    - Provide a mechanism for glucose supplementation.

Treatment of sea transport stress

- ☑ Electrolyte supplements need to treat the specific physiological disorder that is present in cattle and sheep to be effective.
- ☑ No research into the use of electrolytes during shipping has been documented.
- ☑ All of the currently available electrolytes that are suitable for use on a livestock vessel could potentially alleviate stress in cattle and sheep during shipping.
- ☑ An electrolyte supplement for cattle and sheep during shipping should include at least:
    - glucose;
    - sodium chloride;
    - sodium bicarbonate; and
    - potassium chloride.
- ☑ Constituent concentrations of electrolyte supplements for use during shipping would depend on the species and the predominant clinical syndrome that occurs during shipping.
- ☑ Results of land-based studies on the effects of short term electrolyte supplementation on alleviating stress in beef cattle do not allow conclusions to be drawn on the benefits of electrolytes during short-haul shipping.
- ☑ Results of land-based studies on the effects of long term electrolyte supplements indicate that continual electrolyte supplementation of cattle and sheep during long-haul sea transport could be beneficial.
- ☑ Including electrolytes into a treatment regime for individual animals showing signs of heat and nutritional stress during sea transport would be beneficial.
- ☑ Electrolyte supplementation is not a remedy for poor shipping practices.
- ☑ In-water medication through the ship's water tanks is the most suitable method for administering electrolytes on livestock vessels.
- ☑ The ship's master and the water delivery system of the ship will dictate whether differential administration of electrolytes in water on any particular vessel is possible.
- ☑ Administration of electrolytes through the feed may be more cost effective if differential medication is required.

RESEARCH RECOMMENDATIONS

Research recommendation 1

Measure the benefits and costs of supplementing cattle and sheep with electrolytes during sea transport in order to make recommendations on the best use of electrolytes during shipping.

Research recommendation 2

If electrolyte use during shipping is cost effective, determine the added benefit from vitamin, other mineral and amino acid supplementation to electrolyte solutions.

1. INTRODUCTION

1.1 BACKGROUND

It is not known if providing electrolyte supplements to livestock during sea transport is beneficial. The live export industry is divided on the use of electrolytes and there is a need to determine if their administration during shipping is warranted and cost effective. The principal indicator of livestock performance during live export is mortality rate. It is used to monitor industry performance trends over time and as an indicator of individual shipment performance (Norris and Norman, 2000; Ainsworth, 2000). It is also the focus of the general community, who base their perception of live export performance on individual shipments that have particularly high mortalities.

The community's perception is a significant threat to the industry. It is driving greater community support for the RSPCA, which believes that the trade should be banned (Wirth, 2000). The worth of the live export trade to Australia is well documented. LiveCorp figures value it at $708 million for 1999. It provides valuable support to the cattle and sheep industries as a significant market outlet with approximately 25% of the income for Australia's top 20 beef producers being derived from live export (Alliance, 2000). Scientifically verifiable best practice standards that minimise stress, morbidity and mortality are required to overcome the threat of closure to the industry (Trivett, 2000).

Long term mortality trends indicate that the livestock export industry is performing well. The numbers of livestock exported live from Australia have increased substantially over the past decade, yet average annual mortality rates have declined (Norris, 2000; Norris and Norman, 2000). Annual sheep mortalities were approximately 4% in the early 1970s, declined to 2% during the 1980s and in recent years are reported as 1.5% (Gardiner and Craig, 1970; Norris, 2000). Mortalities in the live sheep export trade compare favourably with feedlot deaths. In North American sheep feedlots, death rates range from 0.5%-5% with the majority of deaths occurring in the first 4 weeks after entry to the feedlot (Pierson and Jensen, 1975).

Overall shipboard death rates for cattle have been low, around 0.2% for the previous four years (Norris and Norman, 2000). Mortalities for the Middle East trade were halved in 1999 to 0.35% with twice as many cattle exported that year over the previous year (Norris and Norman, 2000). Cattle live export mortalities compare favourably with death rates seen in feedlots. Average mortalities for cattle in Australian feedlots are 0.7% and most occur in the first 4 weeks (Dunn et al, 1993).

Mortality rates have also been the focus for research. Concerted efforts during the 1980s and 1990s have elucidated the causes of sheep mortalities during live export (Norris, 2000) and studies into the quantification and causes of cattle deaths during live export are just commencing (Norris et al, 2000). However, no research has been done into the effect of electrolytes on live export mortalities or on other performance indicators such as liveweight. Land-based studies measuring liveweight, carcass yield, meat quality and other stress or performance indicators have been conducted to investigate the benefits of electrolytes. However, it is not known whether this information can be extrapolated to shipboard stress and mortalities.

1.2 SCOPE OF THE STUDY

The export of live cattle and sheep from Australia by sea involves three phases. The pre-embarkation phase covers the period from the farm of origin to the arrival of livestock at the ship ready for loading. The shipping phase covers the embarkation of the stock and the period that they are at sea en-route to the port of discharge (Trivett, 2000) and, is the focus of this project. The final, post-shipping phase of the live export process covers all activities that occur at the destination including disembarkation, re-mixing, feedlotting and processing (Table 1).

Table 1: Phases in the export of live animals by sea

PHASE	ACTIVITY
PRE-EMBARKATION	• Preparation on farm of origin • Transport to embarkation site • Assembly at embarkation site
SHIPPING	• Embarkation (loading) • Sea journey*
POST-SHIPPING	• Disembarkation (unloading) • Re-mixing • Feedlotting • Processing

* Activity covered by the present study

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Based on the findings of the review, recommendations for further research are made to enable the development of robust and effective best practice guidelines on the use of electrolytes. It is proposed that field trials and development of new best practice guidelines be carried out in the second stage of this project along with the development of a communication strategy to maximise uptake of the guidelines by industry.

2. METHODOLOGY

The desk top study consisted of a review of the scientific literature and a survey of the live export industry. The findings from the two activities were compared to determine if there was sufficient agreement on electrolyte use to validate best practice guidelines and to inform the development of recommendations for further research.

2.1 LITERATURE REVIEW

The literature review describes electrolytes and their functions and, reviews available electrolyte products suitable for use during shipping. It identifies sea transport stress factors and describes the physiological and clinical effects of these in cattle and sheep. It then considers the benefits of, and techniques for, electrolyte supplementation in treating these clinical syndromes. Findings are generally drawn from land-based studies and current knowledge of veterinary medicine due to the lack of specific shipboard data. Land-based studies on the effects of electrolytes and sugars on liveweight, meat quality and slaughter performance and in alleviating transport stress are reviewed.

2.2 INDUSTRY SURVEY

The survey of the live export industry collected and analysed the opinions of exporters and scientific experts in the field. It was a targeted survey designed to gather views and opinions from experienced exporters and recognised scientific experts in the field rather than as a cross-sectional study of the entire industry. While the sample size was small, the samples selected meant that the survey results do reflect the majority industry view in terms of contribution to industry performance overall.

The survey was essentially the same for both exporters and experts. It aimed to build a picture of how exporters are currently using electrolytes and how experts thought electrolytes should be used. There were sufficient differences between the two groups to confirm that opinion in the industry is divided and that insufficient data exists to draw any conclusions on the cost-benefits of electrolytes or make any recommendations on their use.

2.2.1 Survey of exporters

Survey participants were selected with the assistance of Livecorp and selection was based on the numbers of stock exported annually and experience in the industry. Seventeen exporters received the survey and 8 responded, representing a response rate of 47%. All respondents exported cattle and 3 also exported sheep.

The total number of cattle exported by the survey respondents was 570,000 head per year, which represents 71% of the industry total (Norris and Norman, 2000). The respondents exported 360,000 head to South East Asia and 210,000 to the Middle East and North Africa, which represents 78% and 67% respectively of the industry total. On average, the respondents have been exporting cattle for 10 years (range 5-20). The majority of respondents (75%) exported *Bos indicus*/*Bos indicus* cross cattle that are all export feeder and/or slaughter cattle.

The sheep respondents exported around 2.5 million sheep per year, which represents 50% of the industry total (Norris and Norman, 2000). Their primary market was the Middle East. On average, these organisations have been exporting sheep for 21 years.

2.2.2 Survey of experts

Selection of survey participants was based on recognised experience in the live export field. Thirty-eight surveys were sent and 22 replies were received, representing a response rate of 58%. The survey respondents represented a significant amount of scientific experience and expertise in the live export industry. On average, the respondents have worked in the industry for 12.5 years (range 3-27) with 59% in the industry for more than 10 years. Nineteen (86%) respondents held at least a Bachelor degree. Fifteen of these were veterinarians and the rest held degrees in agricultural science. Of the respondents with a bachelor degree, three also held a masters degree and two had a PhD. Thirteen respondents worked with just cattle, while nine worked with both cattle and sheep.

The survey respondents represented all areas of the live export industry. Ten (46%) of the respondents worked in the industry as either consultants or private practitioners servicing the industry and 12 (54%) worked in government roles providing research, extension and inspection services. Table 2 details the nature of the work undertaken by the respondents.

Table 2: Nature of work undertaken by expert respondents

	No. of respondents	Percent (%)
Type of work undertaken		
Consultant	5	23
Private practice	5	23
Research and extension	8	36
Inspection	4	18
Sector/s of live export chain respondents work in		
All sectors	8	36
Property of origin only	4	18
Assembly and loading only	2	9
Property of origin and assembly and loading	7	32
Destination market only	1	5

3. ELECTROLYTES AND ELECTROLYTE PRODUCTS

3.1 ELECTROLYTE PHYSIOLOGY

An electrolyte is a substance that when dissolved in water, breaks into basic components (ions) that conduct electricity (Phillips, 1997). Electrolytes, together with water and soluble protein form the liquid components of the body and include:

- Sodium;
- Potassium;
- Magnesium;
- Calcium;
- Chloride; and
- Bicarbonate.

The main functions of electrolytes are to satisfy dietary nutrient requirements and maintain the acid-base balance (neutral pH) of the body. Maintaining a constant neutral pH in the body fluids is critical for sustaining life (Ruckebusch et al, 1991). Sodium, potassium and chloride have the greatest impact on blood acid-base metabolism by affecting blood parameters of hydrogen ions (H^+) and bicarbonate (Block, 1994). H^+, bicarbonate and dissolved carbon dioxide (pCO_2) levels determine the acid-base balance (Blood and Radostits, 1989). Acidosis occurs when the pH of the body moves towards acidity, generally due to a loss of bicarbonate ions or an increase in H^+ or pCO_2. Alkalosis occurs when the body becomes alkaline as a result of an increase in bicarbonate or a decrease in H^+ or pCO_2.

Electrolyte treatments or supplements therefore, are aimed at:

- replenishing lost electrolytes; and/or
- correcting an acid-base imbalance.

Key findings

- ☑ Electrolytes are sodium, potassium, magnesium, calcium, chloride and bicarbonate.
- ☑ Electrolytes satisfy dietary nutrient requirements and maintain the acid-base balance of the body.
- ☑ Sodium, potassium, chloride and bicarbonate have the greatest effect on acid-base balance.
- ☑ Electrolyte supplements replenish lost electrolytes and/or correct an acid-base imbalance.

3.2 ELECTROLYTE PRODUCTS

Electrolyte supplements registered for use in cattle and sheep that are suitable for mass medication during shipping are listed in Table 3, together with information on their composition, method of administration and indications for use. Electrolyte products commonly contain non-electrolyte components, for example, sugars, vitamins and sometimes amino acids. Products with dosage and administration requirements that are impractical for live export use are not listed. Data were obtained from the Australian handbook of registered veterinary products (MIMS IVS Annual, 2000) and from the manufacturers. A customised product produced by Topstock WA Feed Services in Western Australia is also included in the table. Shipping Electrolyte, another non-registered, customised product, is available and similar to the Topstock product, although it has not been included in Table 2 because information on it could not be obtained.

Table 3: Electrolyte products suitable for use in cattle and sheep during shipping

Product	Composition	Administration	Indications for use
DEB9®	Electrolytes of sodium, potassium and bicarbonates	In feed	Dehydration and electrolyte imbalance due to heat stress
Selectolyte®	Electrolytes of sodium and potassium and bicarbonates	In water	Dehydration and electrolyte imbalance due to heat stress
Selectrolyte®	sodium bicarbonate (500g) sodium chloride (266g) glucose (179.6g) potassium chloride (50g) vitamin A (2 MIU	In water or in feed	Dehydration and electrolyte imbalance
Solulyte Concentrate®	sodium bicarbonate (500g) sodium chloride (266g) glucose (179.6g) potassium chloride (50g) vitamin A (2.2 MIU)	In water or in feed	Dehydration and electrolyte imbalance
Glucotrans®	glucose (710g) sodium chloride (140g) potassium chloride (50g) sodium sulphate (50g) sodium bicarbonate (40g)	In water	Dehydration and electrolyte imbalance
Topstock Electrolytes	dextrose (400g) sodium bicarbonate (300g) potassium chloride (270g) sodium chloride (25g)	In water	Dehydration and electrolyte imbalance

DEB9® and Selectolyte® are the only products in Table 3 known to be developed specifically for managing heat stress in cattle. They were developed for high performing dairy cattle in tropical environments based on a model developed for the biochemical and physiological responses of cattle to increasing environmental temperature and humidity. Topstock was formulated specifically for the live export trade based on anecdotal experience. Glucotrans® was developed for the feedlot industry to treat the “dead rumen” complex and get cattle on to feed quicker following arrival at the feedlot. The remainder of the products are generic electrolyte supplements.

Key findings

☑ Electrolyte supplements suitable for use in cattle and sheep on livestock vessels are available in Australia and include:

- DEB9®;
- Selectolyte®;
- Glucotrans®;
- Topstock Electrolytes;
- Solulyte Concentrate®; and
- Selectrolyte®.

4. STRESS DURING SEA TRANSPORT

Livestock performance during live export is viewed in a number of ways but is generally focussed on the shipping phase of the process. The commercial perspective of performance for individual shipments centres on liveweight gains or losses for cattle and the number of animals that meet specification at discharge for sheep. The main performance indicators for monitoring the performance of the industry overall and for research have been mortality rates.

Regardless of its definition, livestock performance is governed by the capacity of animals, through genetics and previous experience, to adapt to changes in the environment and maintain body equilibrium (Dantzer and Mormede, 1983; Young et al, 1989). Stress is the adaptive response to these changes (Dantzer and Mormede, 1983) and it has detrimental effects on livestock performance (Kelley, 1980). This can be manifested as liveweight losses and increased morbidity and mortality rates. This results in commercial penalties on individual consignments, a downward trend in industry performance over the long term and an enhanced negative perception of the industry by the general community.

Stress is a major determinant of sub-optimal performance in livestock. Hails (1978) identified disrupted social settings, unusual noise and variations of temperature and humidity as causes of stress. Kelley (1980) supported this, listing the main causes of stress that typically occur in modern livestock production units as: heat, cold, crowding, mixing, weaning, fasting, noise and restraint.

4.1 SEA TRANSPORT STRESS FACTORS

Stress occurs when response mechanisms to changes in the environment exceed normal limits (Coffey, 1988; Blood and Radostits, 1989; Stratakis and Chrousos, 1995). Stressors are environmental factors that elicit the stress reaction when they act as a result of changes in the environment (Selye, 1976). Stress is a general adaptation syndrome resulting from the overburdening of the body's physiological balances due to the cost imposed on it of adapting to stressors (Selye, 1976; McEwen, 1998; Adams, 2000).

Adams (2000) classifies stress on cattle during live export as physical, nutritional, behavioural and infectious, which is consistent with the general view of transport stress as being mainly physical and psychological (Grandin, 1997; Knowles, 1998). Table 4 lists the main stressors and their effects for the different types of stress that are likely during the shipping phase of live export. Behavioural stressors include antagonistic social interactions leading to injury and bruising and psychological stress due to fear. Nutritional stressors are decreased feed and water intake. Physical stressors include heat and injury and, infectious stressors would be the infective agents for salmonellosis and pneumonia.

The most significant causes of stress during sea transport are heat, poor ventilation and fasting. Heat stress and pneumonia are the most common causes of mortalities in cattle during sea transport (Norris et al, 2000; Anonymous, 1988). Although causes of morbidity during shipping are not recorded (Ainsworth, 2000), pneumonia, heat stress, digestive problems (particularly shy feeders) and ketosis are common causes of ill health in cattle during long-haul voyages. These problems are generally not seen during short-haul voyages as *Bos indicus* cattle make up the majority of these consignments and because of the short duration of these voyages (Ainsworth, pers comm). Energy depletion is a common finding in transported and handled cattle (Phillips et al, 1983; Cole and Hutcheson, 1985).

Table 4: Sea transport stressors

STRESS	STRESSOR	EFFECT
BEHAVIOURAL	Novelty	Fear
	Restraint	
	Noise	
	Mixing	Antagonistic interaction
	Overcrowding	
NUTRITIONAL	Fasting	Dehydration Starvation
PHYSICAL	Mixing	Bruising and injury
	Overcrowding	
	Horns	
	Poor ventilation	Pneumonia
	Heat	Hyperthermia
INFECTIOUS	Fasting	Salmonellosis
	Exposure	Salmonellosis/pneumonia

The major causes of death in sheep during shipping are inanition and salmonellosis (Richards et al, 1989) with salmonellosis generally occurring as a result of inanition (Higgs et al, 1993). Although sheep morbidity data are not recorded during shipping (Norris and Norman, 2000), not eating and salmonellosis are significant problems. Heat stress during shipping does occur, particularly when there are sudden rises in ambient temperature and humidity (Norris and Richards, 1989).

The occurrence of heat stress, respiratory distress, pneumonia, inanition and salmonellosis is dependent on a complex interaction of animal, environment and infective agent factors (Blood and Radostits, 1989; Green, 2000). This review focuses on alleviating the effects of these syndromes and does not consider methods for preventing them or discuss the primary causes of them. Therefore, it concentrates on heat and nutritional stress, both of which might be alleviated through the use of electrolytes.

Key findings

☑ The main causes of stress in cattle and sheep during sea transport are:
- Heat;
- Poor ventilation; and
- Fasting.

☑ Heat, poor ventilation and nutritional stress result in:
- Hyperthermia (heat stress);
- Pneumonia (respiratory distress);
- Starvation; and
- Dehydration.

4.2 EFFECTS OF STRESS DURING SEA TRANSPORT

Heat and nutritional stress during shipping could be treated, or their effects minimised, with electrolytes. Understanding what these stressors cause at the physiological level is necessary to effectively alleviate the effects of them. No studies have been done to confirm the exact physiological state of cattle and sheep during shipping. The following findings have been extrapolated from land-based studies and current knowledge of animal physiology. They are limited to the physiological responses of the body to these stresses that may be controlled or alleviated by electrolyte supplementation.

4.2.1 Heat stress

Heat stress causes a rise in respiration rates and deep body temperature (Blood and Radostits, 1989; Adams, 2000). A major heat loss mechanism in cattle and sheep is evaporation of moisture through sweating and from the respiratory tract by panting. Evaporative cooling is the principal heat loss mechanism available to cattle and sheep during shipping and begins at relatively high body temperatures, which can be reached quickly onboard a livestock vessel. Sheep and *Bos taurus* cattle rely mostly on panting to reduce body temperature. *Bos indicus* cattle being more acclimatised to heat, lose body heat by sweating but, will also pant as heat stress increases. Exaggerated respiration with an increase in respiratory rate indicates significant and increasing heat stress (Blood and Radostits, 1989; Adams, 2000).

Heat stress will lead to dehydration and acidosis. Despite hormonal mechanisms being tuned to water and electrolyte retention when animals are under heat stress (El Nouty et al, 1980), continual sweating and increased respiration will result in a loss of body fluids leading to dehydration and electrolyte imbalances. Dehydration can lead to acidosis due to the increase in breakdown of fat, protein and carbohydrate to produce water, which generates acid metabolites (Blood and Radostits, 1989) and due to a decrease in saliva, which contains bicarbonate used for ruminal buffering (Beede and Collier, 1986). While all electrolytes are lost, because sodium is the most abundant ion in the extracellular fluid, it should be an important component of electrolyte supplements (Blood and Radostits, 1989).

As well as being an effect of heat stress, dehydration is also a risk factor for it. A continual loss of body fluids without replenishment will limit the capacity for continual sweating. Maintaining a positive water balance is essential for sustaining evaporative cooling over long periods (Adams, 2000). Cessation of sweating and an increase in panting indicates dehydration and rising heat stress (Blood and Radostits, 1989). Alleviation of the dehydration and electrolyte imbalance will correct the acidosis and enable sweating to continue.

Heat stress can also induce respiratory alkalosis (Beede and Collier, 1986; Schneider et al, 1986). Exaggerated respiration will expel excessive carbon dioxide (CO_2). This reduces pCO_2 and leads to alkalosis (Blood and Radostits, 1989). As the severity of heat stress continues, respiratory evaporative cooling shifts from panting (mouth breathing) in which CO_2 is not expelled, to full respirations and utilisation of the whole respiratory tract where CO_2 is expelled. Persistent alkalosis can also be a risk for heat stress. If alkalosis persists, the body will compensate by depressing respiration to conserve CO_2, which will limit further heat loss (Blood and Radostits, 1989).

The fluid and electrolyte balance of cattle and sheep during shipping is not known. Primary respiratory alkalosis is rare in livestock production systems, however, it could be assumed that continual loss of fluid from the respiratory tract during shipping would lead to dehydration and sodium deficiency. Managing the heat stress, which is the primary problem, with electrolytes will limit dehydration, metabolic acidosis and respiratory alkalosis. To alleviate heat stress, electrolyte solutions would need to restore the acid-base balance as well as the electrolyte balance.

The acid-base balance of cattle and sheep during shipping is not known. Heat stress causes metabolic acidosis and can lead to respiratory alkalosis and the body will compensate for these to try and maintain its acid-base balance. Beede and Collier (1986) suggest providing bicarbonate (to buffer the rumen) and acetogenic agents such as potassium chloride (to counter the alkalosis) to assist in maintaining the blood acid-base balance.

Heat stress in cattle and sheep will also cause nutritional stress. High environmental and body temperatures will reduce feed intake and absorption of nutrients from the gastrointestinal tract (Guerrini, 1981; Mallonee et al, 1985; Beede and Collier, 1986; Schneider et al, 1986).

4.2.2 Nutritional stress

Food deprivation will cause a depletion of glycogen stores, low blood glucose and electrolyte imbalances. Due to the lack of glucose supply, metabolism will change to utilisation of body stores of energy, fat and protein. This will result in life threatening metabolic disorders such as acidosis, ketosis and fatty liver (Blood and Radostits, 1989).

Catabolism of fat and protein produces free fatty acids, which leads to acidosis and fatty infiltration of the liver. Low blood glucose stimulates the liver to produce glucose by an alternative mechanism, which leads to ketone bodies in the blood (ketosis) and low liver glycogen levels (Blood and Radostits, 1989; Lean et al, 1991). While starvation causes electrolyte deficiencies, electrolyte supplements alone will not alleviate starvation as they do not provide the required protein and energy. The main benefit of electrolyte use would be to correct the acidosis and to provide the mechanism and medium for glucose supplementation.

4.2.3 Clinical effects

Heat and nutritional stress will contribute to mortalities during shipping. However, they have a significant impact on other live export performance measures, particularly if stock are slaughtered soon after shipping. As well as mortalities, heat and nutritional stress can cause:

- liveweight loss;
- poor meat quality; and
- reduced carcass yield.

A loss in body weight is a common finding in transported ruminants (Wythes et al, 1980; Hutcheson and Cole, 1986; Knowles, 1998; Knowles, 1999) and it is caused by dehydration as well as starvation (Wythes et al, 1980; Bond et al, 1981; Wythes et al, 1985). Reduced muscle glycogen levels and stress cause dark cutting meat (Fabiansson et al, 1988; Tarrant, 1988). Electrolyte imbalances and dehydration contribute significantly to reduced carcass yield and poor meat quality (Gortel et al, 1992).

Key findings

- ☑ The actual physiological state of cattle and sheep during sea transport is not known.
- ☑ Heat and nutritional stress during shipping have a significant effect on livestock and meat quality. They can lead to:
    - metabolic disorders, particularly:
        - dehydration;
        - acidosis and/or alkalosis;
        - low blood glucose;
        - ketosis; and
        - fatty liver;
    - liveweight loss; and
    - poor meat quality.
- ☑ To be effective, electrolyte supplements used during shipping may need to do some or all of the following:
    - Correct electrolyte deficiencies;
    - Correct acid-base imbalance; and
    - Provide the mechanism for glucose supplementation.

5. TREATMENT OF SEA TRANSPORT STRESS

Electrolyte supplementation should not be considered in isolation as their use alone is not an adequate treatment for the clinical syndromes that occur during shipping. Electrolytes should be a component of an overall welfare program that includes modifying the shipboard environment through improved ventilation and individual treatment programs for livestock as and when required. They are not a remedy for poor shipboard practices.

The survey findings reflected the lack of scientific data on the benefits of electrolytes during shipping and showed a lack of consensus within the industry on electrolyte use. Most experts (60%) believed that electrolytes should be provided during shipping, yet only 31% actually recommended that this should be done. Only half of the exporters surveyed provided electrolytes to livestock during voyages.

In order to determine if there is a cost-benefit of providing electrolytes to cattle and sheep during shipping, two questions need to be answered:

1. What electrolyte formulation is required to alleviate heat and fasting stress that occurs during shipping?
2. What are the benefits of providing the correct electrolyte supplement during shipping?

5.1 COMPOSITION OF ELECTROLYTE SUPPLEMENTS

To be effective, an electrolyte supplement needs to be specifically formulated to correct the physiological disorder that it is being given to treat. What may be appropriate in one production system for one species may not be right for another. Accurately determining the physiological status of cattle and sheep during shipping and diagnosing the predominant clinical syndrome that occurs is needed to formulate the correct electrolyte solution. Dehydration requires a balanced electrolyte solution with higher concentrations of sodium and bicarbonate. Acidosis requires balanced solutions also, but ones that are predominantly bicarbonate. Alkalosis is treated with acidifying solutions, which contain higher levels of potassium or potassium chloride. Malnutrition and ketosis require a simple energy supplement in the form of glucose. The findings of cost-benefit studies into electrolyte use during shipping may be invalid if an inappropriate supplement is used.

To effectively progress understanding on the potential benefits of using electrolytes during shipping, gaps in current knowledge should be filled. These gaps relate to the physiological imbalances caused by heat and nutritional stress during shipping and developing electrolyte products to correct these balances. Issues include:

- Whether or not heat stress is the predominant clinical syndrome and if so determining its major effect: simple dehydration, acidosis due to dehydration or alkalosis due to exaggerated respiration; and
- Whether or not malnutrition and low blood glucose significantly affects performance during shipping.

Based on our findings, an ideal electrolyte for shipboard use would include at least:

- glucose;
- sodium chloride;
- sodium bicarbonate; and
- potassium chloride.

Opinions of survey respondents on this view were mixed. Just over half the experts (55%) agreed for cattle and 44% for sheep, while many did not have a view at all (35% for cattle and 33% for sheep). Half the exporters agreed with this concept while the rest had no view. Relative proportions of the constituents would depend on the species and the predominant clinical syndrome being treated. The levels of glucose and sodium chloride required would depend on whether dehydration or malnutrition is being treated. Sodium bicarbonate and potassium chloride concentrations will depend on whether an acidic or alkaline solution is required.

Richards et al (1989) conducted some work in this area for sheep. They found that inanition was the main cause of death in sheep during shipping and that sheep that died of inanition had fatty livers. Heat stress may have been a factor also as most sheep that died had higher respiratory rates and body temperatures than sheep that lived. However, dehydration was not a significant cause of death in this study. This suggests that an electrolyte supplement with high levels of glucose may be beneficial for sheep. Practical experience in the live cattle industry suggests that cattle are mainly alkalotic due to exaggerated respiration from heat stress (Ainsworth, pers comm), however a solution that is aimed at treating heat stress may still be required as it is the primary problem.

All of the experts that recommended the use of electrolytes recommended Glucotrans® while half of the exporters that use electrolytes, used it. Glucotrans®, with its high glucose concentration, may be more suited for sheep than cattle. Anecdotal evidence suggests that Glucotrans® may be best used in cattle in the assembly depot prior to loading as it has been found to support rumen function and get cattle on to feed quicker (Wood, pers comm). Topstock was developed specifically for the live export trade, yet only one exporter surveyed used it. Topstock with its significant levels of potassium chloride may be most appropriate for cattle. DEB9® and Selectolyte® are marketed as a dietary electrolyte balance management program specifically developed for alleviating heat stress in cattle. This program may be indicated for use during shipping, yet is not well known in the live export industry.

These findings further demonstrate the lack of data and understanding of the benefits of electrolytes during shipping and the need for controlled research into this issue. To best demonstrate cost-benefits of electrolyte use, the right product needs to be used at the right time. To identify the right product, the physiological condition of cattle and sheep during shipping needs to be determined.

5.2 BENEFITS OF ELECTROLYTE USE

Results of studies into the effects of electrolyte supplementation on beef cattle performance are not definitive. Studies in Canada and the United States have reported positive effects on slaughter performance and road transport stress of both electrolyte treatments and diets high in sugars (Hutcheson and Cole, 1986; Schaefer et al, 1990; Gortel et al. 1992; Schaefer et al, 1992; Schaefer et al, 1997). These effects included:

- reduced liveweight loss;
- improved carcase yield; and
- improved meat quality.

The electrolyte products tested in these studies contained electrolytes and glucose in similar amounts to the products in Table 3 however, amino acids were also included in these supplements.

Apple et al (1993) measured the endocrinal response to stress and determined that electrolytes had no effect. Australian studies, using electrolytes and glucose but not amino acids have concurred with this finding. There was no improvement in liveweight loss, carcass weight and muscle pH in cattle supplemented with electrolytes (including Glucotrans® and Solulyte Concentrate®) on-farm and during lairage in southern and northern Australia (Thompson et al, 1990; Pinch, 1993; Phillips 1997; Warner and Pethick, 1999). Non published research into the effects of Glucotrans® on feedlot feed intake did find positive effects (Wood, pers comm). Cattle supplemented with Glucotrans® on arrival at the feedlot settled on to feed quicker than those that did not receive Glucotrans®. It was thought that the electrolytes stimulated functioning of the rumen, which led to a quicker acceptance of the feed.

Phillips (1997) did find improved carcass hydration and meat colour in cattle supplemented with electrolytes and sugar before and after road transport. The supplement in this case was 80% sugar with the remainder being made up of electrolytes. The high sugar content was thought to have stimulated water intake, which led to improved carcass hydration. Warner and Pethick (1999) tested Glucotrans® on-farm and during lairage and found a small increase in muscle glycogen in supplemented cattle. Results were not conclusive and the researchers recommended further studies.

Studies undertaken on the effects of electrolytes in beef cattle have focussed on slaughter and road transport and only studied short supplementation periods of up to 3 days. These results could not be extrapolated to long-haul sea transport where electrolyte supplementation could continue for 1-3 weeks. Results could be applied to short-haul sea transport if the studies were conclusive. Given the lack of definitive findings from these studies and the fact that *Bos indicus* cattle, which are more heat tolerant, make up the bulk of short-haul consignments, electrolytes may not be required for these shipments. However, this would need to be confirmed. Most experts (57%) and 32% of exporters believed that electrolytes should be provided to all cattle during short-haul sea transport.

In contrast, studies using long term electrolyte supplementation in dairy and feedlot cattle have found definite positive effects, particularly when the animals were heat stressed. Adding simple electrolytes to dairy cattle diets during hot summers increased daily feed intake and enhanced milk production (Schneider et al, 1984; Mallonee et al, 1985; Beighle et al, 1988; Tucker et al, 1988; West et al, 1992; Block, 1994; Silanikove et al, 1998). Feedlot performance of steers was also enhanced, with long term electrolyte supplementation resulting in higher feed intakes and weight gain (Ross et al, 1994). These findings and the findings of Richards et al (1989) indicate that continual supplementation with electrolytes of cattle and sheep during long-haul sea transport could be beneficial in alleviating the effects of heat and nutritional stress. However, controlled trials would need to be done to confirm this and determine the cost benefit. The majority of experts (61%) and 49% of exporters agreed that electrolytes should be provided to all cattle during long-haul transport, while 66% of experts and 34% of exporters felt the same for sheep.

Electrolytes are indicated for treating heat stroke (Wagner, 1987) and excessive sweating (Armantano and Solorzano, 1987) and, the benefits of electrolytes in improving athletic performance of race horses are well recognised (Harkins et al, 1994).

The addition of other electrolytes, vitamins and protein (amino acids) to electrolyte supplements should be considered. Vitamins and minerals can enhance the immune response (Blecha, 1988; Dubeski et al, 1996) and vitamins A and E boost resistance to respiratory disease (Green, 2000). Amino acids may have been responsible for the effects seen in previously quoted studies. However, single treatments with vitamins A, D and E were found not to ameliorate the physiological response to transport stress or prevent weight loss (Bajhau, 1991; Jubb et al, 1993; Mudron et al, 1994; Mudron et al, 1996). Again, the effects of supplementing for longer periods are not known. Magnesium supplements may also enhance performance and liveweight gains in cattle (Grings and Males, 1988; Zinn et al, 1996) although it is not soluble in water. Hence, studies investigating the effects and cost benefits of adding vitamins, minerals and protein to electrolyte solutions during live export may be warranted, if simple electrolyte solutions are found to be beneficial and cost effective.

There was general agreement from survey respondents on the general benefits of electrolytes during shipping. Most experts (81%) and 50% of exporters felt that electrolytes should be included in the shipboard treatment regime for cattle, and 77% of experts and 33% of exporters felt the same for sheep. This provides support for the Shipboard Management Program and we recommend that the current industry practice of including electrolytes in the shipboard veterinary kit continue.

5.3 CURRENT PATTERN OF ELECTROLYTE USE

In gathering expert opinion on using electrolytes during shipping, the industry survey aimed to build a picture of current usage of electrolytes by exporters and experts. Overall, the numbers of exporters that used electrolytes was small, there was a disparity between exporters and experts and, there were a large number of “no view” responses made by the experts. Hence, it is difficult to draw conclusions on the current pattern of electrolyte use. This finding supports the need for further research in this area.

On the question of when electrolytes should be used, 44% of experts had no opinion for cattle. Of those that had an opinion, the majority (66%) felt that it should be all year round.

For sheep, 67% of experts had no opinion and of those that had an opinion, half agreed that they should be given all year. All exporters that used electrolytes used them all year round.

On the question of whether *Bos taurus* cattle should receive electrolytes throughout an entire voyage, 39% of exporters agreed while 39% had no opinion. For *Bos indicus* cattle, the number of experts with no opinion was 44% with 33% believing that they should receive electrolytes for the whole voyage. Of the exporters who used electrolytes, 60% provided them for the entire voyage.

Half the experts believed that *Bos taurus* cattle should receive electrolytes during both long and short-haul voyages and 39% had no opinion. For *Bos indicus* cattle, 33% felt they should receive electrolytes during both long and short haul voyages and 44% had no view. Of the exporters who used electrolytes, half provided them during short-haul only and 35% for both long and short-haul trips.

On the question of which stock on a voyage should receive electrolytes, 44% of experts felt that whole shipments of *Bos taurus* cattle should be treated and 49% had no opinion. For *Bos indicus* cattle, 44% felt the whole shipment should be treated while 44% had no opinion. For sheep, 67% had no view, while 28% felt that the whole shipment should be treated. Of the exporters who used electrolytes, half treated the entire shipment.

No conclusions can be made on the current use of electrolytes in sheep. For cattle, there appears a trend towards supplementing entire shipments of *Bos taurus* cattle all year round for the entire length of long-haul voyages. Based on comments received from the survey, a net benefit-cost may be derived from the strategic use of electrolytes on animals at the highest risk, rather than with general use. However, more data is required before any recommendations on the best use of electrolytes can be made.

Key findings

- ☑ Electrolyte supplements need to treat the specific physiological disorder that is present in cattle and sheep to be effective.
- ☑ No research into the use of electrolytes during shipping has been documented.
- ☑ All of the currently available electrolytes that are suitable for use on a livestock vessel could potentially alleviate stress in cattle and sheep during shipping.
- ☑ An electrolyte supplement for cattle and sheep during shipping should include at least:
    - glucose;
    - sodium chloride;
    - sodium bicarbonate; and
    - potassium chloride.
- ☑ Constituent concentrations of electrolyte supplements for use during shipping would depend on the species and the predominant clinical syndrome that occurs during shipping.
- ☑ Results of land-based studies on the effects of short term electrolyte supplementation on alleviating stress in beef cattle do not allow conclusions to be drawn on the benefits of electrolytes during short-haul shipping.
- ☑ Results of land-based studies on the effects of long term electrolyte supplements indicate that continual electrolyte supplementation of cattle and sheep during long-haul sea transport could be beneficial.
- ☑ Including electrolytes into a treatment regime for individual animals showing signs of heat and nutritional stress during sea transport would be beneficial.
- ☑ Electrolyte supplementation is not a remedy for poor shipping practices.

5.4 ADMINISTRATION METHODS

Electrolytes are provided to animals either mixed with feed, dissolved in water or administered directly by injection. The advantages and disadvantages of these administration methods are outlined in Table 5. The most suitable method of administering electrolyte products during shipping is in the water (Guerrini, 1981; Schaefer et al, 1992; Phillips, 1997; Wood, pers comm).

Table 5: Methods for electrolyte administration

Method	Advantages	Disadvantages
In water	• More accurate dosing particularly with water medication systems • More immediate effect	• Need to add to ship's water tanks or to each water trough
In feed	• Easy mass dosing by mixing into feed storage units	• Potential for uneven mixing and clumping leading to inaccurate dosing • Feed intake decreases during heat stress • Inanition is a major problem in sheep during shipping
Injection	• Good for individual animal treatment	• Not practical for mass medication

There are several ways of providing electrolytes in water (Phillips, 1997):

- Adding the supplement directly to troughs;
- Adding to the water tank that supplies the troughs; and
- Using a water medication system.

Adding the supplement to the ship's water tank is easier for mass medication however, agreement is needed from the ship's master and there is the potential for wastage of the supplement. Any water containing supplement that is left at the completion of the voyage would need to be discarded. Supplements containing sugars will ferment if left standing (Phillips, 1997). Most experts (77%) agreed that adding electrolytes to the water tanks is a useful method. If mass medication is not required, then target treatment of pens containing animals in need of treatment by adding the supplement to the pens' water troughs can be done. However, only 30% of experts and 30% of exporters felt that this was a useful method. Despite the disadvantages of in-feed medication, survey respondents felt that it was a more useful technique than adding to the water troughs of each pen.

Recommendations on the best methods of electrolyte administration during shipping should be made if electrolyte supplementation during shipping is found to be cost effective.

Key findings

- ☑ In-water medication through the ship's water tanks is the most suitable method for administering electrolytes on livestock vessels.
- ☑ The ship's master and the water delivery system of the ship will dictate whether differential administration of electrolytes in water on any particular vessel is possible.
- ☑ Administration of electrolytes through the feed may be more cost effective if differential medication is required.

6. FURTHER RESEARCH

The findings of the desk top study indicate that there is insufficient data to support any recommendations on the best use of electrolytes during shipping. Specific research is required and was supported by the majority of survey respondents. Strong support was obtained for studies into electrolyte use during both long-haul (95% of experts and 84% of exporters) and short-haul (95% of experts and 66% of exporters) of cattle. Support for the use of electrolytes for sheep during shipping was also strong (79% of experts and 67% of exporters).

We recommend that the following research be conducted in the listed priority order.

Research recommendation 1

Measure the benefits and costs of supplementing cattle and sheep with electrolytes during sea transport in order to make recommendations on the best use of electrolytes during shipping.

This could be done in a number of ways and we have presented two options. We recommend Option A because the methodology would engender greater confidence in the outcomes than Option B, but Option A would be more expensive and take longer.

Option A

1. <u>Determine the most appropriate electrolyte supplement for cattle and sheep during shipping</u>

Objectives

To determine the predominant clinical syndrome that occurs in cattle and sheep during sea transport by describing electrolyte balance, acid-base balance and metabolic disorders.

Materials and methods

- This can be done by examining animals and collecting samples during actual voyages. However, using a predictive model based on data already collected may be a more cost-effective alternative.
- A model for dairy cattle in tropical environments that predicts physiological changes to varying environmental temperature and relative humidity has been developed by Rural Chemical Industries (RCI), the manufacturer of DEB9® and Selectolyte®. They believe that the electrolyte management program they have developed from this model is appropriate for cattle during shipping and would have positive effects. This model (and the treatment program) could be appropriate for live export and should be verified by an independent expert.
- Verify the RCI model of physiological changes in cattle to increasing temperature and relative humidity. If verified, then examine it for its suitability for sheep.
- Once verified, enter data on the nature and composition of the shipboard environment (gaseous composition, temperature and humidity) that are currently being generated by the MAMIC ventilation study to determine the physiological state of cattle and sheep during shipping.
- If the model cannot be verified, then there may be sufficient data available to enable the development of a specific live export model.

- The integrity of the model could be tested, particularly for cattle, under experimental conditions on land. The data generated by the MAMIC ventilation study suggests that shipboard conditions can be replicated in an animal house. There are animal houses in Australia capable of undertaking these studies. A suggested protocol would be:
  - 3 – 5 animals per group;
  - use sufficient groups so that the major types of animals that are exported live are represented;
  - replicate daily shipboard conditions for long and short-haul voyages;
  - conduct daily clinical examinations, weighing, blood and urine analysis and post mortem analysis on completion; and
  - undertake analyses for glucose, ketones, fatty acids, liver enzymes and electrolyte levels.
- The model and animal house studies may not be able to predict the extent of ketosis that is likely during shipping and therefore may under estimate the glucose requirement. This is important for sheep where inanition has a large effect on mortalities during shipping. Therefore, shipboard studies may still be required for sheep. Such a study could also validate the acid-base balance findings of the model. A suggested protocol would be:
  - select three long-haul shipments of sheep: one each of low, medium and high risk shipments (based on key risk factors identified in the accompanying LIVE.104 report: Influence of pre-delivery management, or as identified by a performance monitoring system recommended in the same report);
  - randomly select a number of pens (depending on the number of pens in the ship) so that all areas of the ship are represented;
  - randomly select 1-2 sheep per pen and individually identify them;
  - collect blood samples once every three days from identified sheep;
  - undertake blood analysis for glucose, ketones, fatty acids, liver enzymes and electrolyte levels.
- Based on the model outputs, examine available electrolyte products to determine the most suitable product for cattle and sheep during shipping. If none can be found, develop a new electrolyte supplement specifically designed to correct the physiological condition found in cattle and sheep during shipping.

2. <u>The cost-benefit of supplementing cattle and sheep with electrolytes during shipping</u>

Objectives

To quantify the benefits and costs of electrolyte supplementation of cattle and sheep during shipping.

Materials and methods

- Use the supplement identified or developed from Trial 1.
- Select three long-haul shipments of cattle and sheep: one each of low, medium and high risk (based on key risk factors identified in the accompanying LIVE.104 report: Influence of pre-delivery management, or as identified by a performance monitoring system as recommended in the same report).
- Select as many lines of animals as practical to constitute the intake of study animals.
- Use a cohort study design where the performance of animals that are supplemented with electrolytes (treatment group) is compared to the performance of animals from the same line that are not treated (control group).

- Randomly allocate animals in each line (or a sample if there are a large number of animals in the line) to a treatment and control group.
- Ensure that the treated and control animals from each line are penned in the same part of the ship. The performance of the lines of animals are not being compared, therefore the placement of lines on the ship is not an issue. However, performance of animals within each line is being compared. Therefore, all animals of a particular line need to be penned together so that the treated and control animals are exposed to the same shipboard micro-environment.
- Measure liveweight at embarkation.
- Identify treatment and control pens and provide the supplement to the treatment pens for the duration of the voyage.
- Measure daily feed intake, morbidity and mortality data together with internal and external environmental parameters for the duration of the voyage.
- Measure liveweight at disembarkation.
- Monitor destination feedlot performance.
- Compare performance of the two groups for each line to examine the effect of electrolyte supplementation.

Option B

<u>The cost-benefit of supplementing cattle and sheep with electrolytes during shipping</u>

Under this option, the most appropriate electrolyte supplement would not be determined. Therefore, a number of commercially available supplements would be tested and their effects compared against each other and against a control.

We recommend the DEB9®/Selectolyte® electrolyte management program, Topstock and Glucotrans® be evaluated in this trial as these have been specifically developed for live export or for conditions similar to those experienced during live export. The manufacturers of DEB9® and Selectolyte® and Topstock are willing to collaborate and provide product for the purposes of the trial at little or no cost.

Objectives

To quantify the benefits and costs of electrolyte supplementation of cattle and sheep during shipping.

Materials and methods

- Select three long-haul shipments of cattle and sheep: one each of low, medium and high risk (based on key risk factors identified in the accompanying LIVE.104 report: Influence of pre-delivery management, or as identified by a performance monitoring system as recommended in the same report).
- Select one large line of animals to constitute the intake of study animals.
- Use a cohort study design where the performance of animals that are supplemented with one of three electrolytes (three treatment groups) are compared to each other and to the performance of animals that are not treated (control group).
- Measure liveweight at embarkation.
- Record the pens of all study animals.

- Allocate the pens into treatment and control pens by random systematic sampling. This will help avoid bias in the study from location on the ship by having treated and control pens randomly distributed within the study line.
- Provide DEB9® and Selectolyte® to one treatment group, Topstock® to another and Glucotrans® to the third treatment group for the duration of the voyage.
- Measure daily feed intake, morbidity and mortality data together with internal and external environmental parameters for the duration of the voyage.
- Measure liveweight at disembarkation.
- Monitor destination feedlot performance.
- Compare performance of the treatment groups against each other and against the control group to examine the effect of electrolyte supplementation.

Research recommendation 2

If electrolyte use during shipping is cost effective, determine the added benefit from vitamin, other mineral and amino acid supplementation to electrolyte solutions.

There are many substances that could be added to electrolyte products that could have a positive effect on live export performance. Vitamins A and E may reduce the effects of respiratory disease, amino acids may counteract inanition in sheep and magnesium is thought to be beneficial. There is limited evidence to justify the cost and time of investigating each of these individually and the cost of delivering single supplements may outweigh the benefit. However, measuring the possible synergistic effect of supplementation of these additives to electrolyte products may be feasible where a cost effective delivery system was already in place. The implementation of the industry performance monitoring system as described in the accompanying LIVE.104 report: Influence of pre-delivery management, would greatly facilitate this work.

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