The Effect of Post-transport Electrolyte Supplementation on the Dressing-out Percentage of Cattle, Tested Under Commercial Conditions.

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ABSTRACT

The commercially used electrolyte supplement Multigro, was diluted with water and supplied to cattle as a dilute electrolyte solution. The cattle were being held in the lairage area of an export licensed meat works, and experienced normal commercial lairage conditions. The electrolyte solution was supplied to the cattle through the trough system in the lairage area. The aim of the experiment was to measure whether the cattle supplied the solution achieved a greater dressing out yield compared to cattle that were supplied water only in the lairage area.

A total of 83 animals, made up of a combination of steers and bulls, were split into two treatment groups; cattle supplied water (W), ($n = 41$), and cattle supplied electrolyte (E), ($n = 42$). The cattle came from different commercial farms all within a 40 minute transportation journey of the meat plant. Two other experiments were also conducted, the first attempted to determine the water requirements of cattle in lairage. The second aimed to identify whether cattle preferred the electrolyte solution offered to water by offering both solutions to a roup of cattle at the same time.

The use of this electrolyte solution failed to improve the dressing-out percentage, under commercial conditions. It is suggested that the reason for this result was due to the failure of the animals to gain adequate rest while in lairage. It is further suggested that this inability to rest adequately meant that the animals never fully recovered from the influence of stressors affecting their behaviour in lairage, the result being the homeostatic control mechanism would still have been operative, assisting the animal in adjusting to its new surroundings, but not allowing its muscles to rehydrate and achieve a normal, rested, homeostatic balance.

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TABLE OF CONTENTS

LIST OF TABLES

page.

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

The treatment of cattle from the farm paddock to the knocking box subjects the animals to a variety of stressors. If the duration of exposure to the stressor(s) is prolonged or intense, detectable changes in the homeostatic, physiological and behavioral responses of animals can occur. The animal is then said to be in a state of stress (Stephens, 1980). Stress can be detrimental to both the welfare of cattle processed through a meat plant (Kilgour, 1988) and the economic returns of the processor (Tarrant, 1981).

Stress has been identified as a main cause of economic loss in the meat industry as it increases the occurrence of Dark, Firm and Dry (DFD) meat in beef carcasses. This has led to research which has identified some of the sources of stress in the movement of cattle from the farm to slaughter (Tarrant, 1988). The identification of these stressors has led to new lairage designs and handling practices. These focus upon decreasing the behavioral response of cattle as they interact with stressful environments (Grandin, 1979; 1980).

Recently, theories have been put forward that suggest the movement of cattle from the farm to slaughter may be incurring greater economic penalties than just the occurrence of DFD. It is known that stress can affect the homeostatic and physiological mechanisms of cattle, which become responsive during their reaction to stressors (Shaw and Tume, 1992; Gortel *et al.* 1992). These responses lead to an interaction in the body between the nervous and endocrine systems (Stephens, 1980), which when combined with time off feed and water during transport, followed by possible restricted access to lairage water supplies, may be having a profound effect upon an animal's homeostatic water balance.

The reaction of an animal to external and/or environmental stimuli was referred to, by Hans Seyles, as the General Adaptation Syndrome (GAS) (Seyles, 1946 *via* Grossman,

1987). This refers to the endocrine system, which caters to long-term homeostatic and physiological responses and the nervous system for sensory inputs and the short term responses (Blood *et al.* 1983). That an animal must adapt to any external demands that are abnormal, be they unfamiliar handling practices or freezing temperatures, is agreed upon. The exact interactions between the neuro-endocrine axis which acts in concert with other physiological systems to negate the effects of the stressors, is not yet fully understood (Grossman, 1987).

Recent theories put forward by Schaefer *et al.* (1990; 1992), are that a cattle beast, when dealing with emotional and physical stressors, experiences physiological changes, these include changes in the level of essential minerals, plasma metabolites and hormone concentrations present in the blood. Schaefer *et al.* suggests that cattle under stress have a lower body water content which at the time of slaughter decreases the dressing-out percentage. Gortel *et al.* (1992), stated that as the changes cattle experience are physiological in origin they are essentially treatable, and recommends treatment using an electrolyte solution.

Recent research by Schaefer *et al.* (1988; 1990; 1992), Gortel *et al.* (1992) and Jones *et al.* (1988; 1990; 1992) has indicated that there are real and tangible benefits to be gained, in the form of improved carcass weights, through the supply of an electrolyte solution to cattle prior to slaughter. Their research identifying significant dressing-out percentage improvements that were made possible via the supply of these electrolytes.

Electrolytes have already been proven to be beneficial for the rehydration of children (Hirschhorn and Greenough, 1991), and calves (Mitchell *et al.* 1992) suffering from diarrhoea and are used to aid in the recovery of horses after intensive training or racing (Cohen *et al.* 1993). In most cases the emphasis behind the use of electrolyte was to improve the rate of water uptake by the body, and increase the retention time of the water in the body. After the success of Schaefer *et al's.* (1992) study, they suggested that it was time to examine the value of supplying an electrolyte solution to cattle in a commercial situation.

Therefore, this research trial examines the feasibility behind supplying an electrolyte solution to cattle prior to slaughter in a commercial situation, based upon any changes in the carcass yield of the cattle trialed. In this study an electrolyte supplement which is currently supplied to animals orally in a concentrated form, was diluted and supplied to cattle through the lairage trough system of a commercial abattoir, using an electrolyte formula that is similar to that used by Gortel *et al.* (1992).

A point to note, the establishing of individual carcass weight losses to within 1% can be difficult due to variables in the relative live weights, marketing treatments, different states of gut fill and nutritional history of the cattle leaving the farm. Therefore experiments studying carcass yields do require large numbers to identify any significant effects (Shorthose *et al.* 1988; Wythes, 1984).

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

A beef carcass is made up of muscle, fat, and bones. Each of these are made up of a varying proportion of water, lipids, protein and ash. The loss of any of these components prior to slaughter will reduce the dressing-out percentage of an animal. Bone loss is unlikely, due to the very slow turnover of this component. The loss of muscle or fat in any quantity from the carcass may be the result of catabolism, but is more likely to be the result of either bruising, contamination, or excess fat being removed from the carcass during the standard carcass trim which is applied in export licensed meat plants (Refer to Appendix 2). However, dressing-out percentage losses may also occur as a consequence of a cattle beast having a lower than normal muscular water content at the time of slaughter.

This water loss from the carcass may be due to dehydration of the muscle cells, the loss of sodium from the extracelluar spaces, or due to catabolism of the fat and muscle cells for energy and water (Wythes, 1984; Shorthose and Wythes, 1988). The size of the loss, in terms of the dressing-out percentage, is negatively related to the animals state of hydration upon arrival at the meat plant, its current bodily demand for water and its ease of access to available lairage water.

Mammals have developed a homeostatic mechanism designed to protect them against water deprivation at times of shortage. Between mammals these mechanisms operate in a remarkably similar fashion. For this reason, reference has been made to humans, horses, sheep, and dogs to explain how some of these mechanisms work in cattle.

It is the objective of this study to firstly, via the literature review, overview an animal's homeostatic balance, and the mechanisms involved in maintaining this state of balance.

Also, to identify the sources of stress a cattle beast has to deal with prior to slaughter, and how stress may effect an the animal's behaviour and its homeostatic and physiological balances. Secondly trials were conducted to examine the effect that supplying an electrolyte solution to cattle prior to slaughter has upon an their dressing-out percentage. Finally the results of these trials are discussed, and recommendations are made with regards to future work that is required.

2.2 BODY WATER AND ELECTROLYTES

Formerly, under the 1969 New Zealand Meat Regulations, there was a policy of holding all cattle in lairage for 24 hours prior to slaughter, but more recently meat companies have been allowed to introduce the practice of "tail-gating" where-by ante-mortem inspection is carried out on the day the stock arrive, allowing stock to be killed, if required, within hours of their arrival. This change in MAF policy has had a considerable influence on potential carcass weight losses as it shortens the time the cattle are off feed, while still having access to water.

The reason water has such a large effect on over all yield is that it is the most abundant and easily transferable compound in the body of an animal, making up around 60% of an animal's total live weight (Mason, 1972; Mitchell *et al.* 1989). Putting this into perspective, it means a steer with a live weight of around 600 kg contains around 360 kg water.

The total body water of an animal is held in two major compartments :

(a) Intra cellular fluid (ICF) accounts for approximately 66% of the total body water.

(b) Extra cellular fluid (ECF) makes up approximately 33% of the total body water.

Although these two compartments differ markedly in electrolyte composition, they are in a state of osmotic equilibrium and water can diffuse freely between them along the

osmotic gradient. The relative volume distribution of water between the two is governed primarily by the number of osmotically active particles in each compartment. The ECF volume is governed by the sodium (Na^+) concentration and the ICF by the potassium (K^+) concentration (Carlson, 1989).

ECF consists of all fluids located outside of the cells and includes plasma (0.05 L/kg), interstitial fluid and lymph (fluid in the lymph vessels) (0.15 L/kg), and the trans-cellular fluids, which includes the fluid content of the gastrointestinal tract (Carlson, 1989). The gastrointestinal tract, when dry matter is included, can account for up to 22% of the animal's live weight (Shorthose and Wythes, 1988). In ruminants, fluid in the gastrointestinal tract can also act as a reservoir during periods of water restriction (Denton, 1982).

The ECF volume is vitally important because a reduction in water content due to water intake being less than output will increase plasma osmolality. This in turn can force the movement of water from the intracellular space, or increase the excretion of Na^+, until osmolality is achieved, thereby reducing the dressing-out percentage (Mitchell, 1983).

Table 1 : The Balanced Plasma Electrolyte Concentrations of Domestic Animals.

	Ox	Horse	Sheep
Sodium (mmol l^{-1})	132-152	132-146	139-152
Potassium (mmol l^{-1})	3.6-5.8	2.6-5.0	3.9-5.4
Chloride (mmol l^{-1})	95-110	99-109	95-103
Bicarbonate (mmol l^{-1})	20-30	24-30	20-25
pH	7.35-7.5	7.32-7.44	7.32-7.54
Osmolality (mOsm/kg H_2O)	270-300	270-300	-

(Carlson, 1989; Blood et al. 1983).

A healthy animal, that has adequate access to food and water, and is rested, can be presumed to be in a state of Na^+, K^+, acid-base and water balance. In this state there is no net gain or loss of water, and the plasma electrolyte composition is maintained

within narrow limits (Refer to Table 1). However, during the transportation and holding of cattle for slaughter, a water imbalance could be created as a result of stress and water deprivation which may be causing a reduction in the final dressing-out-percentage.

There are two objectives which must be satisfied when taking cattle from the paddock to slaughter to ensure carcass yield losses are minimised. These are the regulation of extracelluar osmolality, and regulation of ECF volume. Both events depend on the water intake equalling the water loss, and the maintenance of the ECF Na^+ concentration (Crowley *et al.* 1989).

2.3 CONTROL OF BODY WATER AND ELECTROLYTE BALANCE

When considering the effects of stressors in relation to changes in an animal's body water and electrolyte balance, and in potential carcass yield losses, it is important to firstly have an understanding of the animal's body composition in relation to its actual water volume (Section 2.2), and secondly to know which electrolytes elicit the greatest control over the animal's water balance (Section 2.3), and finally to have an understanding of which physiological mechanisms are involved in maintaining the body water and electrolytes in a state of balance (Section 2.4).

Table 2 : The Effects of Supplying Fluids to Cattle on their ECF Volume .

Parameters	Control (n=4)	Water (n=3)	Water + Electrolytes (n=3)
Fluid Intake (L)	0	29.7±3.9	17.0±3.4
ECF Volume (L)	92.5±8.3	142.8±9.6	127.9±9.4
Plasma Volume (L)	16.7±1.9	18.7±2.3	16.6±2.3

(Gortel et al. 1992).
Control : No fluids supplied.
Electrolyte formula refer to Table 32.

The above Table 2 provides an indication of the size the ECF volume of a 550 kg bull held in lairage for 18 hours, after 4 hours of transport. Table 3 gives the daily water demand of beef cattle. These tables provide a brief insight into the fluid volumes a cattle beast deals with.

Gortel *et al.* (1992), found that when measuring the affects of supplying fluids to bulls as opposed to a period of water deprivation, the fluids greatly increased the animal's ECF volume (Refer to Table 2). In Gortel's study, the plasma volume for both the control and electrolyte groups were virtually the same, yet the ratio of plasma to ECF volume was vastly different. The suggestion was that the control group would have to have drawn fluid from the interstitial fluid and ICF to protect the circulating plasma fluid volume and maintain an osmotic equilibrium between ECF and ICF.

Table 3 : Water Requirements of Beef Cattle .
(NRBC. 1984).

TABLE 6 Approximate Total Daily Water Intake of Beef Cattle[a]

Weight		Temperature in °F (°C)[b] 40 (4.4)		50 (10.0)		60 (14.4)		70 (21.1)		80 (26.6)		90 (32.2)	
kg	lb	liter	gal	liter	gal	liter	gal	liter	gal	liter	gal	liter	gal
Growing heifers, steers, and bulls													
182	400	15.1	4.0	16.3	4.3	18.9	5.0	22.0	5.8	25.4	6.7	36.0	9.
273	600	20.1	5.3	22.0	5.8	25.0	6.6	29.5	7.8	33.7	8.9	48.1	12.
364	800	23.8	6.3	25.7	6.8	29.9	7.9	34.8	9.2	40.1	10.6	56.8	15.
Finishing cattle													
273	600	22.7	6.0	24.6	6.5	28.0	7.4	32.9	8.7	37.9	10.0	54.1	14.
364	800	27.6	7.3	29.9	7.9	34.4	9.1	40.5	10.7	46.6	12.3	65.9	17.
454	1000	32.9	8.7	35.6	9.4	40.9	10.8	47.7	12.6	54.9	14.5	78.0	20.
Wintering pregnant cows[c]													
409	900	25.4	6.7	27.3	7.2	31.4	8.3	36.7	9.7	—	—	—	—
500	1100	22.7	6.0	24.6	6.5	28.0	7.4	32.9	8.7	—	—	—	—
Lactating cows													
409 +	900 +	43.1	11.4	47.7	12.6	54.9	14.5	64.0	16.9	67.8	17.9	61.3	16.
Mature bulls													
636	1400	30.3	8.0	32.6	8.6	37.5	9.9	44.3	11.7	50.7	13.4	71.9	19.
727 +	1600 +	32.9	8.7	35.6	9.4	40.9	10.8	47.7	12.6	54.9	14.5	78.0	20.

[a] Winchester and Morris (1956).
[b] Water intake of a given class of cattle in a specific management regime is a function of dry matter intake and ambient temperature. Water intake is quite constant to 40°F (4.4°C).
[c] Dry matter intake has a major influence on water intake. Heavier cows are assumed to be higher in body condition and to require less dry matter and, thus, less wa intake.

2.3.1 Potassium

Potassium (K^+) is the third most abundant mineral element in the animal's body, and the principal cation of the ICF. ICF K^+ is stable at around 78 mmol l^{-1} in the adult cattle (NRBC, 1984). The distribution of K^+ is coupled to the active extrusion of Na^+ from the cells which is maintained by an energy dependent sodium-potassium pump at the cell membrane (Carlson, 1989). Potassium makes only a small contribution to the extra-cellular osmotic pressure and therefor ECF volume.

Unlike Na^+, K^+ intake in herbivores is high due to the amount of K^+ found in their feed. As an example, a horse on an all hay diet may have a daily K^+ intake of around 3,000-4,000 mmol l^{-1} per day, the majority of this would be excreted. Therefore cattle are less well adapted to deal with shortages of K^+ in their diet. Internal K^+ balance is influenced by changes in aldosterone, Na^+ delivery to the distal nephron, hydrogen ion (H^+) excretion, glucocorticoids, exercise, ADH and catecholamines (Finco, 1989; Carlson, 1989).

Due to the high content of pasture K^+, healthy cattle with a substantial gut-fill should not have a problem with K^+ deficiency. Schaefer *et al.* (1992), recorded that cattle entering the lairage area had plasma K^+ concentration of 3.36 mmol l^{-1}, which, while fluctuating slightly, was still 3.60 mmol l^{-1} after 36 hours of food and water deprivation.

When considering plasma K^+ concentrations in the context of stress, its main controlling factor is aldosterone. Stress as a result of trauma or hypovolemia leading to muscle catabolism, releases large amounts of K^+ into the ECF, this has the direct effect of increasing the secretion of aldosterone, which is important in sustaining K^+ secretion in the kidneys (Espiner, 1987). Refer to Section 2.3.3 on Aldosterone.

2.3.2 Sodium

ECF is dominated by the electrolyte Na^+, and contains approximately one half to two-thirds of the body's total Na^+. Sodium ion provides the equivalent of an osmotic

skeleton for the ECF. Osmoreceptors detect small changes in ECF osmolality and influence thirst and anti-diuretic hormone release for the restoration, conservation, or concentration of body water. (Crowley *et al.* 1989). With a few exceptions the osmotic gradients across cell membranes are rapidly dissipated by water movement (Mitchell, 1983). ECF volume depletion is generally a reflection of the underlying loss of Na^+ (Mitchell *et al.* 1989).

Sodium is kept in the ECF via a Na^+ pump, along with the appropriate amount of water to maintain normal plasma Na^+ concentrations and osmolality (Mitchell *et al.* 1989). The control of Na^+ balance rests primarily with the homeostatic mechanisms affecting the kidneys. These mechanisms are: osmotic factors; renal perfusion pressure; and the release of aldosterone (Finco, 1989). The key role of the kidney is to regulate plasma volume and composition (Mitchell and Navar, 1989; Mitchell, 1983), in part this is done by maintaining the concentration of plasma electrolytes, dominated by Na^+, within narrow limits (Refer Table 1).

In New Zealand the main source of Na^+ for cattle is in pasture, which is recognised as being low in sodium chloride (NaCl) (NRBC, 1984). Cattle therefore are well adapted to dealing with a shortage of Na^+ in their diets, acute Na^+ depletion usually being the result of excessive excretion of Na^+ containing fluid, eg. via diarrhoea.

2.3.3 Body Water Balance

Water output, or loss, is closely related to work load, the environment and climatic conditions. Body water is controlled by hormonal regulators, including the antidiuretic hormone (ADH), aldosterone, and the renin-angiotensin system. Water is lost through excretion, sweat and breathing (NRBC, 1984).

Cattle have three sources of water input available to them,

(a) drinking water,

(b) water content in feed stuffs,

(c) metabolic water derived by oxidative metabolism or catabolism. The oxidation of 1 gram of fat, carbohydrates or protein produces 1.07g, 0.06g, and 0.41g of water respectively (Carlson, 1989).

The failure of an animal to supply itself with enough fluid to maintain its water balance will lead to dehydration. This will result in a direct loss of carcass weight, possibly due to catabolism of the body tissue for water, or the movement of water from the ICF to the ECF, because of increasing plasma osmolality. Increasing plasma osmolality stimulates the release of ADH, and renin, which in turn stimulates thirst (Espiner, 1987). Plasma osmolality is controlled within a narrow range, rarely changing more than 2-5 osmol/kg, drinking is stimulated within this range, given ready access to water (Denton, 1982).

When referring to an animal as dehydrated, it is to cellular dehydration of greater than 1 percent, and to a body weight loss no greater than 4 percent. This is because it is assumed that most cattle entering the lairage area, post transport, would be thirsty, rather than being perceived as clinically dehydrated (Table 4). In Table 4 it is shown that an animal can lose up to 4% of its total live weight before a state of dehydration is detectable. Table 4 also describes the effect of dehydration on live weight.

Animals, when drinking to restore a fluid deficit, will only drink an amount appropriate to the size of that deficit. Water-depleted sheep precisely corrected a water deficit of 10% of body weight in 1-3 minutes. Significant absorption of the water was apparent in 30-60 minutes from the time of drinking. Thrasher *et al.* (1981), noted a similar result in dogs (Denton 1982). The suggestion is that a cattle beast will drink once, then not drink again until the secretion of ADH initiates a new thirst response. With reference to sheep, Denton (1982) states that the time between water balance and the onset of cellular thirst requires a 1-3% reduction in cellular water.

Table 4 : The Degrees of Severity of Dehydration and Guidelines for Assessment.

Body Weight Loss (%)	Sunken eyes, Shrunken face.	Skin fold test persists for (sec.)	PCV[1] (%)	Total plasma solids (g/l)	Fluid required to replace volume deficit (ml/kg body wgt.)
4-6	Barely detectable	-	40-45	70-80	20-25
6-8	++	2-4	50	80-90	30-50
8-10	+++	6-10	55	90-100	50-80
10-12	++++	20-45	60	120	80-120

(Blood et al 1983)
1 : Packed Cell Volume (Haematocrit)

In summary it can be assumed that cattle arriving at the meat plant are, in most cases, in a state of good health. Cattle have a developed homeostatic control mechanism which, under normal conditions and allowing for adequate access to water will maintain their water balance, without substantial changes to the internal milieu of the animal. The question arises as to what happens during the movement of cattle to slaughter, when it is assaulted by stressors that require alterations to its internal milieu beyond the range of its normal standards.

2.4 REGULATION OF THE WATER VOLUME AND pH OF THE BODY FLUIDS

Cattle that are in the marketing process from the farm to slaughter are often placed in situations which can lead to water deprivation (eg. transportation), changes in ECF electrolyte balance, or a change in their acid base balance due to excess physical exertion. These changes can cause adjustments in the homeostatic mechanisms controlling the animal's salt balance and water volume. These mechanisms activate the release of ADH, the renin-angiotensin system, aldosterone secretion, and ECF and ICF buffers, though not necessarily all at once. How these mechanisms affect body water volume and tonicity are important to understand.

2.4.1 Acid-base Balance

The acid-base balance is an indicator of the state of balance, in the ECF, between the anions and cations. In cattle under duress there is potential for the development of metabolic acidosis caused predominantly by the build-up in lactic acid in the skeletal muscles. The occurrence of acidosis can lower the muscular pH from 7.0 to 6.4 (Tarrant, 1988). The pH of the body fluids is very closely regulated by the ECF and ICF buffers, the CO_2 removal by the lungs and ultimately by H^+ excretion by the kidneys.

In domestic animals the lungs and the kidneys play dominant roles in the acid-base regulation. The kidneys especially being ultimately responsible for the excretion of H^+ ions. Metabolic acidosis is the build up of H^+ ions in skeletal muscles, the kidneys' role at times of acidosis allows for the conservation of HCO^-_3 and the excretion of H^+ ions alkalosis being the reverse (Finco, 1989).

The advantages of supplying electrolytes for the treatment of acidosis, may only occur if the cattle can be rested adequately enough, allowing the electrolytes to be used to bolster the already substantial blood buffering capacity that a ruminant possesses (Novotna and Zemanova, 1986). In reality, animals that do develop acute acid-base imbalances are often diagnosed with some dysfunction not caused by the marketing process (Blood *et al.* 1983). Therefore treatment via the supply of electrolytes may offer no real benefits to these individual animals.

2.4.2 The Effect of the Anti-Diuretic Hormone (ADH)

ADH is a major determinant of water homeostasis, it is synthesized in the hypothalamus and released from the posterior pituitary in response to increases in plasma osmolality (Baylis, 1989). ADH secretion is highly sensitive to small changes in plasma osmolality, a 1% change in plasma osmolality can initiate ADH secretion. It is therefore largely responsible for maintaining ECF tonicity by its action on the kidney of increasing water reabsorption (Espiner, 1987). ADH is also secreted in response to

decreases in effective circulating volume, although the renin-angiotensin system exerts primary control over volume changes.

The major roll of ADH is to alter the principal cells' (located along the entire collecting ducts of the kidney), permeability to water. This allows increased amounts of water to be reabsorbed back into the blood system. The primary control is the body's need for water conservation. ADH has a half life of 2-3 minutes, therefore the release of ADH is constantly self adjusting in relation to plasma osmolality and water supply (Carlson, 1989).

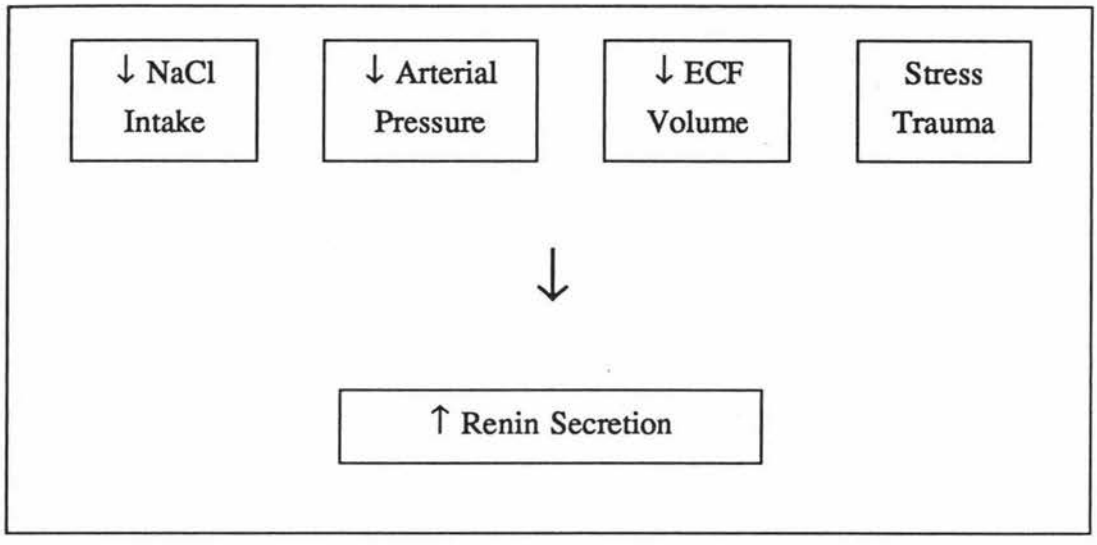
ADH is secreted in response to increased osmolality, which in turn stimulates a thirst response, if water cannot be obtained ADH will stimulate water conservation through the kidney. El-Nouty *et al.* (1980), using cows, showed it was also released in response to heat stress increasing the EFC volume (Refer to section 2.7.1 Climate). Importantly, while ADH does respond to environmental stressors affecting water balance it is not recognised as being affected by emotional stressors.

2.4.3 The Effect of the Renin-Angiotensin System (RAS)

The RAS plays an important part in the maintenance of effective circulating fluid volume (Mitchell and Navar, 1989). Renin is released in response to reduced renal perfusion (fluid movement) produced by dehydration or increased sympathetic activity.

Renin converts to angiotensinogen, which converts to the biologically active angiotensin II (A-II). A-II increases the renal retention of Na^+ and water by enhancing the secretion of aldosterone and having a direct effect on the renal tubule (Carlson, 1989; Mitchell and Navar, 1989; El-Nouty *et al.* 1980). Figure 1 outlines the four major reasons as to why renin is secreted.

Figure 1 : The Major Factors Regulating Renin Secretion.



A-II stimulates thirst, salt appetite, and ADH secretion. It increases hepatic gluconeogensis (formation of glucose by the liver) and glycogenolysis (liberation of glucose from glycogen in the liver), and stimulates salt and water absorption by all segments of the intestine. A-II also indirectly affects the renal absorption of salt and water via its direct stimulatory effect on the secretion of aldosterone (Mitchell and Navar, 1989).

In general A-II acts to promote the conservation of salt and water and the maintenance of ECF volume and arterial blood pressure, through the release of renin (Mitchell and Navar, 1989).

2.4.4 The Effect of Aldosterone

Aldosterone is a mineralocorticoid from the adrenal cortex. In the kidneys the effect of aldosterone on the distal tubules consists almost entirely on the exchange of Na^+ with K^+ and H^+ (Espiner, 1987). An increase in aldosterone concentration in plasma increases Na^+ reabsorption and increases K^+ excretion. Aldosterone also facilitates the return of K^+ to ICF in exchange for Na^+.

El-Nouty *et al.* (1980) observed low aldosterone levels in heat stressed cattle. They theorised that this was due to the increase in ECF volume as well as increased intra-renal pressure both combining to reduce renin release. Significant decreases in plasma and urinary K^+ may have inhibited aldosterone release, as an increase in plasma K^+ increases aldosterone secretion (Mitchell, 1983; Ganong, 1989).

There are four major factors that control or directly stimulate the secretion of aldosterone. They are plasma K^+ and Na^+ concentration, A-II and the adrenocorticotropic hormone (ACTH). A-II plays the major role (Mitchell and Navar, 1989). A point to note, Ganong (1989), states that under normal circumstances the plasma Na^+ concentration must drop about 20mmol l^{-1} to stimulate aldosterone secretion, alternatively plasma K^+ need only rise by 1mmol l^{-1} to stimulate the same secretion. From this Ganong concludes that changes in plasma Na^+ are not as important in the release of aldosterone as K^+.

The ultimate effect of the Renin-Angiotensin-Aldosterone system is to elicit a substantial control on urinary Na^+ excretion thereby playing a major role in the maintenance of extracelluar tonicity.

2.4.5 The Effect of the Adrenocorticotrophic Hormone (ACTH)

ACTH is secreted by the pituitary gland. The secretion being stimulated predominantly by the corticotrophin releasing hormone (CRH) and ADH, while A-II and possibly other hormones may also play a part (Gaillard and Al-Damluji, 1987). The adrenocorticotrophic hormone (ACTH) influences the adrenal cortex, and its predominant action is the stimulation of steroidogenesis and corticosteroid release from the adrenals, although the precise role of ACTH still remains unknown (Mol and Rijnberk, 1989).

ACTH increases the secretion of the adrenocortical hormones (Espiner, 1987), and the action of ACTH on the adrenal gland is very rapid; within minutes of its release, there is an increased concentration of steroids in the adrenal venous blood (Rijnberk and Mol,

1989). There are two adrenal cortical hormones that are important in the context of this research, they are:

(a) Mineralocorticoids (aldosterone and deoxycorticosterone) which maintain salt balance.

(b) Glucocorticoids (cortisol and corticosterone) primarily involved in carbohydrate metabolism (Rijnberk and Mol, 1989).

The release of ACTH in response to stressors is linked closely with the control of salt and water balance. ACTH secretion stimulates corticosteroids, which include aldosterone, cortisol and to a lesser extent corticosterone, all have some mineralocorticoid action (Espiner, 1987).

The sustained stimulation of the adrenal cortex by ACTH due to stressors, increases aldosterone and cortisol secretion, each having different long term effects. Over time the aldosterone response will begin to wane so that 'normal' or even low levels of aldosterone are found after 24 hours, cortisol secretion is maintained, overall lessening the Na^+ retaining effects. This result will be over-ridden if the driving force behind aldosterone secretion is A-II as a result of hypovolemic stress (Espiner, 1987).

2.4.6 The Effect of the Sympathetic Nervous System

In the theory of natural selection stress responses evolved because they provided the means to react to threats and hence the survival rate of an animal was improved. This was achieved through control of its internal milieu by short term adjustments to homeostatic systems Responses to stress vary according to internal or external stimuli.

To meet these internal and external challenges response patterns have evolved. Mitchell and Navar (1988), concluded in their study that the response of cattle to stress has two phases, a hypothalamic-adrenal cortex phase which is associated with perceived stress such as noise, and the sympatho-adrenal-medullary system (SAMS) which is associated

with neurogenic (stimulated by the nerves) stress, such as transport or, specifically, the massive sympathetic discharge caused by stunning. Combinations of stressors will produce a mixed response.

2.4.6.1 The Hypothalamus

The hypothalamus is the main subcortical centre regulating sympathetic-activity. Stimulation of the hypothalamus can produce disturbances in blood pressure, body temperature, drinking, eating, emotional behaviour and sleep. Stimulation of the posterior hypothalamic 'defense area' increases heart rate and blood pressure. Stimulation of specific hypothalamic regions can elicit different patterns of responses of plasma catecholamines. The antreoventral third ventricle region of the anterior hypothalamus is involved with neuro circulating adjustments related to body fluid regulation. The hypothalamus also stimulates the posterior pituitary to release ADH into the blood stream (Mol and Rijnberk, 1989). The hypothalamus is believed to be the main site determining patterned responses of stress systems such as the SAMS (Goldstein, 1987).

2.4.6.2 Responses of the Sympatho-Adrenal-Medullary System

2.4.6.2.1 Cardiovascular

SAMS activation increases cardiac output enhancing the delivery of oxygen and glucose throughout the body. Blood volume is redistributed, blood is moved from the peripheral regions to preserve pressure to the heart and brain. There is also increased blood flow to skeletal muscles and decreased skeletal muscular resistance to blood flow in preparation for increased muscular effort especially during 'fight or flight' responses (Goldstein, 1987).

2.4.6.2.2 Gastrointestinal

This is an important part of digestion. The level of the SAMS' response required to cause this response is not clear, but its stimulation generally inhibits gut mobility and suspends the digestive process. Splanchnic vasoconstriction shunts blood away from

the intestines to the heart, brain and skeletal muscles (Goldstein, 1987). This may also occur during strenuous exercise, and animals under stress are recorded to have stopped ruminating, which may be in conjunction with this response.

2.4.6.2.3 Metabolic

SAMS activation increases the availability of glucose by stimulating gluconeogensis and glycogenolysis by the liver, increasing the secretion of glucagon, and inhibiting insulin secretion. Catecholamine-induced lipolysis aids thermogenesis, and adrenalin decreases plasma K^+ (Goldstein, 1987).

It should be noted that the release of ADH, renin-angiotensin system, aldosterone and ACTH all come under the influence of the SAMS.

2.4.7 The Effect of Renal Perfusion Pressure

During the pre-slaughter period a cattle beast comes into contact with a variety of stressors, some of these forms of stress require the animal to protect its state of water and electrolyte balance, other forms of stress are not directly associated with changes in the ECF and/or blood circulating volume, but may stimulate the secretion of the hormone systems directly concerned with them, even when the animal's homeostatic balance is not threatened. Because of this the animal has to have an over-riding control mechanism to ensure that its salt and water balance are maintained within narrow limits, and a state of over-hydration does not occur (Espiner, 1987).

The over-riding control mechanism, used to ensure that a potentially harmful state of over-hydration cannot occur, is found in the kidney, using the renal perfusion pressure. Renal perfusion pressure is a major factor in determining the effects of stress associated hormones on salt balance. With dehydration the renal perfusion pressure and the rate water is excreted from the body will fall, augmenting the Na^+ and water retaining effects of the stress response mechanisms being stimulated. If, however the animal involved is in a state of homeostatic balance when stress response hormones are released, the increased pressure brought upon the kidneys over-rides the effects of the water and

electrolyte retaining hormones. Thus it is the renal perfusion pressure that largely determine the effects of salt and water retaining hormones on salt and water balance (Espiner, 1987).

2.5 ANIMAL STRESS IN THE MEAT INDUSTRY

Many of the management practices to which cattle are subjected during the marketing process are potent stressors. A lot of work has been conducted on the physiological effects of stressors on cattle between the farm gate and the knocking box (Refer to reviews by Stephens, 1980; Cockram, 1990; Jones and Tong, 1989; Lister, 1988). Unfortunately the majority of this work has occurred in countries like Australia, Canada, England and USA, where climatic, transport, and handling conditions differ to those found in New Zealand.

One of the most marked differences is in transport distances. In Australia the average time to slaughter is 2-5 days (Wythes, 1984). Also in some of these countries there is a much higher proportion of meat animals reared indoors, which would give handlers greater contact with their stock. Grandin (1993), states that cattle which have had previous handling experience settle down more quickly at the slaughter plant stockyard facility.

The removal of animals from feed for a time prior to slaughter, leading to weight loss (Jones *et al.* 1988; 1990; Purchas, 1992; Wythes *et al.* 1982; 1983; 1984), is unavoidable, due to transportation requirements and lack of feeding facilities in New Zealand lairage areas. The aim of processors and producers should be to either minimise this time off feed, while still satisfying MAF requirements for animal inspection or to minimise the stressors that may increase carcass weight loss. Purchas (1992), stated that potential weight loss due to feed deprivation may be accentuated by marketing stressors.

As referred to at the start of this thesis, Stephens (1980) stated that stressors could change the homeostatic or physiological responses of an animal, and that these changes

could be to the detriment of the welfare of the animal. Before examining these stressors in the context of the marketing processes and its effects on cattle, stress needs to be defined.

2.5.1 Stress Defined

Defining stress has become more difficult as research into it has expanded and even today an agreed definition of stress has not been acknowledged by researchers (Goldstein, 1987). A notable issue in defining stress is the separation of 'stress' as a response from 'stressor' the environmental stimulus requiring a response.

Blood *et al.* (1983), defines stressors as "environmental factors which stimulate homeostatic, physiological and behavioural responses in excess of normal".

and

Stress as "any stimulus, internal or external, chemical, physical or emotional, that excites neurons of the hypothalamus to release corticotrophin - releasing hormones at rates greater than would occur at that time of day in the absence of the stimulus"

Blood *et al.* (1983), actually uses stress instead of stressors in this definition, by stating that "stress is a stimulus", but as a final definition it is adequate. Stress in this study is the result of an animal coping with either an isolated stressor, like dehydration, or cumulative stressors, ie marketing of cattle to slaughter.

Stress under the influence of the fore mentioned conditions manifests itself in the form of changes, from normal, in the animal's homeostatic balance and behavioural differences. These changes resulting from the activation of the animal's SAMS, maintain the animal's internal environment by short term adjustments in the activities of the homeostatic system (Goldstein, 1987). The difficulty in defining stress accurately is that each animal's patterned response is unique and there is a wide variation in effects of the alterations on an animal's internal milieu (Mitchell *et al.* 1988).

2.5.2 Stress and Dark, Firm and Dry Beef

Stress in cattle arises during the marketing of animals from the farm to slaughter. Tarrant, (1981), in an international (n=27) survey estimated that the occurrence of stress related meat quality defects, predominantly Dark, Firm and Dry (DFD) beef, was 1-4% in heifers and steers, 6-10% in cows, and 11-15% in bulls.

These figures have led to the implementation of new lairage design and pre-slaughter management practices in an attempt to address the causes of stress symptoms in cattle. These include, transportation and handling (Mitchell *et al.* 1988; Kenny and Tarrant, 1987), feed and water deprivation (van de Walt *et al.* 1993; Wythes *et al.* 1984; 1989), nutritional status (Hutcheson and Cole, 1986), and the break down of the herd hierarchy and social structure due to mixing and/or over-crowding during transport and in lairage (Mohan *et al.* 1991; Tarrant *et al.* 1988).

Stress in cattle is often measured in terms of the development of DFD, which occurs due to the depletion of glycogen reserves in the muscle cells prior to slaughter (Lawrie, 1991). Meat that is graded DFD cannot be used for prime export cuts because of its aesthetically unpleasing colour, and it's poor keeping qualities, making it difficult to preserve in a vacuum packed bag (Lawrie, 1991).

> The question is, 'does stress only create a tangible cost due to meat quality defects or are stressors affecting the dressing-out percentage as well ?'

Schaefer *et al.* (1990; 1992), and Gortel *et al.* (1992), state that stress does incur extra costs on the meat industry through losses in the dressing-out percentage.

The rapid breakdown of glycogen in the living muscle may be triggered by increased concentrations of circulating adrenaline, Stephens (1980); Blood *et al.* (1983), released when an animal's homeostatic system alters due to one or several stressors eliciting a 'fight or flight' response, or by strenuous muscular activity (Tarrant, 1988). When

examining these two responses it is notable that the homeostatic responses to stressors eliciting glycogen breakdown also influences salt and water balances.

2.5.3 The 'Fight or Flight' Response

The 'fight or flight' response is elicited in a cattle beast that has been alarmed (Tarrant, 1988; Stephens, 1980; Blood *et al.* 1983). This reaction results in the release of corticosteroids. The emergency reaction to such alarms is characterised by the mobilisation of the body resources for immediate action (Stephens, 1980).

Notable responses are the increases in heart rate, cardiac output, and blood pressure, indicating the release of renin. Glucose is released in quantity from the liver for use by the skeletal muscles, indicating the secretion of adrenaline. Blood is redistributed from the skin and viscera to the central nervous system and muscles. Muscle capillaries dilate allowing for easier flow of blood to them. Within seconds the bronchi become enlarged and the lymphocyte, blood coagulating factors, and creatine kinase are released to aid in the repair of damaged tissue (Stephens, 1980).

Other hormones released in response to the stress include, glucagon, catecholamine and glucocorticoids, which include corticosterone, cortisol and cortisone (Brett, 1988). These are designed to increase glucose production and lipolysis (energy metabolism). Therefore their roles are related to the metabolic adaptation to stress (Brockman and Laarveld, 1986). Aldosterone is also released in response to changes in plasma K^+ concentrations, caused by catabolism if the physical response is prolonged.

If the stress persists the animal adapts by secreting corticotrophin-releasing hormones from the hypothalamus. When these hormones reach the anterior pituitary the ACTH is released. This in turn causes the adrenal cortex to release more corticosteroid hormones into the general circulation at an increased rate. The increased adrenalin output from the adrenal medulla stimulates the anterior pituitary gland to release ACTH. The entire mechanism is controlled by a negative feedback system which cuts-off the above sequence when the stressor is no longer active (Stephens, 1980), and increased

renal perfusion pressure over-rides the salt and water retaining effects of the mineralocorticoids (Espiner, 1987).

2.5.4 The Physical Response

A stress response can be invoked by strenuous muscular activity, usually the result of either mixing different herds, the disruption of a herd's hierarchy or when struggling to maintain balance during transport. The second and third causes are often the result of over-crowding (Tarrant *et al.* 1988).

To meet the energy demand of working muscles anaerobic respiration is triggered, this system utilises glycogen stores in the muscle, producing lactic acid as a by-product of the process. If the animal is unable to remove either the accumulated lactic acid or heat from the muscle, equal to its rate of production, the muscular pH will fall and the temperature will rise, increasing the rate of water loss (Judge *et al.* 1989).

In horses, strenuous exercise during training caused changes in fluid and electrolyte balances (Cohen *et al.* 1993). These changes, measured studying thoroughbred horses after strenuous exercise, are as follows; an increased concentration of Na^+ in the blood, increased fractional urinary excretion of Na^+, a decreased concentration of chlorine (Cl^-) in blood, decreased fractional urinary excretion of Cl^-, increased urinary and plasmal osmolality, weight loss, and a decreased pH of the blood.

Horses lose a lot of water and salts through the skin, cattle, while not sweating to the same extent, can exert themselves to the point of physical exhaustion, especially if mixing occurs (Blood *et al.* 1983). A point to note in comparing cattle to race horses, is that cattle are notoriously inactive, using a minimum of required daily energy in movement. Therefore, a cattle beast's rate of recovery would be a lot slower than a horse (Lister, 1988).

Three factors listed by Cohen are relevant to this thesis.

(1) Changes in electrolyte balances are recognised under both adrenergic and contractile stress mechanisms (Schaefer *et al.* 1988; 1990; 1992; Jones *et al.* 1992).

(2) Strenuous exercise may result in a weight loss problem in the meat industry. Purchas (1992), recorded a 4.5 kg carcass weight improvement over 4 hours compared to 28 hours holding time in lairage.

(3) Severe physical exertion increases plasma osmolality. This may result in fluid being redistributed, and body water balances adjusted. Major shifts of fluid may also occur from ICF to ECF if blood pressure is threatened (Carlson, 1989).

In summary electrolyte imbalances can occur as the result of loss of electrolytes, or due to the loss of water, as an animal responds to stressors (Blood *et al.* 1983). Stress, as the result of marketing stressors, can results in biochemical changes that seem to be physiological in origin. Stressors that lead to an electrolyte and/or water imbalance in horses, calves and humans can be treated with oral rehydration solutions, indicating that the same imbalances may be able to be addressed in adult cattle.

2.5.5 Sources of Animal Stress in the Meat Industry

In New Zealand three main influences on physiological change to cattle in the marketing process are climate, transportation, and lairage. Within these important stressors that can accentuate the effects include stocking density, mixing, rest, feed and water withdrawal, nutritional history and handling.

2.5.5.1 Climate

Temperature affects cattle differently from humans in that during exposure to heat, cattle, will either maintain or increase the volume of urine excreted relative to that observed at thermoneutrality, while humans concentrate their urine to provide water for intense sweating (El-Nouty *et al.* 1980). The increase in urinary excretion depends on the size of the increase in water consumption during the heat exposure (El-Noulty *et al.*

1980). The implication is that cattle use water consumption and urine excretion as a thermo-regulator.

Often the effects of climate are accentuated when an animal has not adapted to unseasonal climatic conditions (Shorthose and Wythes, 1988). For example the Ames Wind Chill Indices on cattle with summer coats recorded temperatures down to -17°C at 65 km/hr during an actual temperature of 10°C. This would decrease again if the animal was wet.

During sudden cold exposure, shivering is the major contributor to enhanced heat production and may increase oxygen consumption fourfold (Tarrant, 1988),and decrease water consumption (Young, 1975). Climate therefore does effect water demand (El-Nouty *et al.* 1980), and an animal's critical temperature, although this will depend upon the animal's nutritional status (Lister, 1988). Animals subject to progressive cold will attempt to increase heat production as they pass their lower critical temperature.

Table 5 shows the results from El-Nouty *et al's.* (1980) study on the effect of heat stress on cattle

Table 5 : The ADH and Aldosterone Response to Heat Stress and Dehydration in Cattle.

	Thermoneutrality with Water. (20°C, 50% RH) (*n=60*)	Heat Exposure with Water. (35°C, 50% RH) (*n=64*)	Heat Exposure without Water. (35°C, 50% RH) (*n=20*)
Water Consumption (Litres/hd/day)	50.32	59.31	0.0
ADH (pg/ml)	1.25±0.05	2.11±0.07	4.77±0.75
Plasma Aldosterone (ng/100ml)	21.76±1.12	13.99±1.22	10.55±1.46
Rectal Temperature (°C)	38.4	39.5	40.4
Urine Volume (L/day)	18.6	20.9	9.2
Hours in Experiment.	113	113	30

(El-Nouty et al. 1980)
Cattle fed alfalfa hay cubes to maintenance.

El-Nouty *et al.* (1980), studied the effects of heat stress on cattle with and without water. Heat caused a significant increase in plasma antidiuretic hormone (ADH) concentration in cattle. They drew two important conclusions from the trial in relation to the effects of climatic changes on cattle.

(1) A rise in deep body temperature will cause a significant rise in ADH.

(2) The decrease in renin-angiotensin-aldosterone levels during heat exposure may result in increased urine output.

Other important results recorded were that plasma osmolality decreased significantly during heat exposure, partly due to the significant decrease in plasma sodium concentration caused by the increase in urinary sodium excretion and the increased water retention. Note that water consumption went up 9 l/day yet urine production only went up by 2 l/day. Heat exposure resulted in no significant changes in the haematocrit[1] percent. Dehydration under heat resulted in significant increases in haematocrit percent (El-Noulty *et al.* 1980).

Reduction in plasma aldosterone levels under heat was associated with a significant drop in plasma Na^+ and a slight increase in urinary Na^+ excretion. Dehydration caused the plasma Na^+ to increase significantly, over and above thermoneutrality and heat alone levels. Heat alone saw a drop in plasma and urinary K^+ compared to thermoneutrality, although dehydration significantly raised plasma K^+ compared to heat.

El-Nouty *et al.* (1980), only looked at one aspect of climate, that of heat stress, also, in this trial the water offered contained 40 mg Na^+/l and 10 mg K^+/l. The influence of Na^+ in the water may also have played a part in improving water retention. El-Nouty *et al.* (1980), identified ADH, aldosterone and the renin-angiotensin system as all playing potential roles in the maintenance of body temperature during heat stress, through body fluid control, and increased body water retention.

1 haematocrit : is the volume of red blood cells in the blood expressed as a percentage, it refers to ml of red blood cells per 100 ml of blood, in cattle it is 40 (Dukes, 1955).

Cold exposure may also cause substantial body fluid reductions in cattle, when initially exposed to cold stress (Young, 1975). Young noted a 13-24 kg live weight loss in cattle, in the first three days of cold exposure, also increased metabolic rate, blood haematocrit, and increased plasma concentrations of glucose and free fatty acids, and decreased skin temperatures. The suggestion was that cold exposure caused a weight loss due to shifts in body fluids causing peripheral vaso-constriction, increasing renal perfusion pressure, which was compensated for by a decreased water intake, until the animals acclimatised.

Atkinson (1992) studied the effect of transport on plasma electrolyte concentrations and dermal skinfold thickness of calves. As the distance travelled increased from 0 to >280 km the skin thickness increased from 45 mm to 51 mm ($p<0.05$). Atkinson stated that the increase in skin thickness was an indication of dehydration during transportation, but did not mention the effect that wind chill may have had on the calves.

Schaefer *et al.* (1988) recorded that cattle experiencing longer transportation distances and time off feed displayed the lowest skin temperatures. These results supported those of Romanyuk (1982), who demonstrated a reduced body core temperature in transported bulls. The effect of this drop in skin temperature would see blood drawn away from the bodies extremity, indicating increased influence of the RAS, and could be mistaken for dehydration.

2.5.5.1.1 Climate and Nutritional Status

The state of gut fill of a ruminant is controlled by the time it is taken off feed, the time of the year, (determines pasture quality and feed intake rates), and finally the feed regime it is operating under. ie. is it feeding to body maintenance, or above or below maintenance (Kilgour and Dalton, 1984).

An example of the effect of temperature on cattle is expressed by the state of their body condition and current feed intake. Cattle being fasted in a temperate climate have a critical temperature (CT) of 18°C, cattle being fed a maintenance diet will have a CT

of 6°C, and animals which are in a state of weight gain have a CT of 1°C (Shorthose and Wythes, 1988). Jones and Tong (1989) also suggested that seasonal change had a detrimental affect on meat quality, especially in lighter animals.

The inference of all this is that what an animal has had to eat before it leaves the paddock will influence how soon its body begins to catabolize body tissue, thereby eliciting the secretion of homeostatic hormones, such as aldosterone.

2.5.5.2 The Transportation of Cattle

In New Zealand cattle are not usually transported large distances. Longer distances are associated with greater weight losses, though not necessarily increased stress responses (Shorthose and Wythes, 1988). In New Zealand actual distances travelled by stock can vary considerably. The bigger New Zealand meat companies generally would transport livestock to their nearest operating plant from the point of purchase, but single plant operators may be required to get a proportion of their stock from further afield than just the surrounding district, to maintain the operation of their plant.

Shorthose and Wythes (1988), indicated that transportation is the source of several stress responses induced by water and/or feed deprivation, psychological, physiological, and physical stressors, and usually a combination of these. They suggested that cattle can adapt to transport, thereby decreasing its stress affect over time.

The actual effects of transport on cattle seem to vary between studies. Stephens (1980), in his review, stated that if transportation conditions are adverse the adrenal response to the stressor is immediate. A novel stimulus being the most potent stressor for cattle of all ages. Stephens (1980), cites the transportation of calves for periods ranging from 1-4 hours as being a greater stressor than castration, dehorning or 48 hours water withdrawal, measured in the terms of elevated plasma corticosteroids, like cortisol.

This is in contrast to Mitchell *et al.* (1988), who recorded higher cortisol levels in handling than from transporting cattle. Transport did cause a sixfold increase in the

secretion of adrenalin, not seen during handling (Refer to Table 6). Tarrant (1990), suggested that short haul transport is not associated with the occurrence of DFD in beef except during trauma, but does not deny that short haul transport is a potent stressor.

Cattle do experience transportation stress, eliciting a patterned stress responses. As the duration in transportation continues the effects of feed and water deprivation become more pronounced, and the stress of transport recedes. Combined with this are the effects of climate, stocking density, and time in lairage. All ultimately influence the rate of dressing-out percentage loss (Hutcheson and Cole, 1986).

2.5.5.2.1 Changes in Blood Metabolites and Hormones, in Response to Transportation Stress

Transportation stress elicits various physiological responses, which may ultimately result in changes to an animal's salt and water balance. Mitchell *et al.* (1988), established plasma concentrations of key stress metabolites and hormones in unstressed cattle, and in cattle experiencing the stressors associated with transport and slaughter. Table 6 is a summary of their results.

The standard deviation for ACTH, cortisol, and catecholamines in the above measurements indicates that there is a large variation between individual animals. Over the 20 hours from control to slaughter the initial increases in ACTH and cortisol began to wain, this is in agreement with the statements by Espiner (1987).

Table 6 : The Average (±sd) Blood Haematocrit, Metabolite, and Plasma Hormone Concentrations in Cattle Subject to the Stresses of Transport and Slaughter.

Group		Control (*n=21*)	Transport (*n=10*)	Slaughter (*n=10*)
Haematocrit	(%)	28.03±3.0	45.5±3.4	45.0±2.4
Total Protein	(g/L)	78.0±9.0	77.0±13.8	65.5±10.4
Plasma Lipid	(g/L)	1.7±0.4	6.5±1.5	5.0±1.4
Plasma Lactate	(mmol l^{-1})	0.3±0.2	5.0±1.3	7.9±2.6
Plasma Glucose	(mmol l^{-1})	4.0±0.6	5.5±0.7	6.0±0.7
ACTH	(μiu/ml)	20.6±7.9	116.8±74.3	104.8±91.4
Cortisol	(nmol/L)	25.0±13.7	89.3±67.0	71.3±35.3
Adrenaline	*(ng/ml)*	*1.7±0.8*	*9.6±6.5*	*9.0±16.4*
Noradrenaline	*(ng/ml)*	*0.0*	*1.1±1.9*	*6.4±9.2*
Total Catecholamines	(ng/ml)	1.7±0.8	10.7±6.6	15.4±22.3

(Mitchell et al. 1988)
Control : Unstressed cattle accustomed to handling.
Transport : 180km by road, 2 hr. journey.
Slaughter : Stunning with captive bolt.

Mitchell's *et al.* (1988), results are similar to those found by Kenny and Tarrant (1987a), although their resting cortisol concentration was 5 times lower than Mitchell's. Kenny and Tarrant (1987a), in their results, also supplied a plasma creatine kinase (CK[1]) value, and recorded an elevated heart beat (Refer to Table 7). Eichinger *et al.* (1991), recorded elevated plasma concentrations for cortisol 93.9 nmol l^{-1}, glucose 5.59 mmol l^{-1}, and lactate 5.98 mmol l^{-1}, after 45 minutes transport followed by pre-slaughter handling.

The increases in cortisol levels are indicative of prolonged or intense stress. Cortisol is known to have lipolytic and Na^+ retaining effects (Eichinger *et al.* 1991). Elevated catecholamine levels directly accelerate muscle glycogen depletion (Tarrant, 1988). Cortisol is also required if catecholamines are to function properly (Shaw and Tume,

1 : CK is released in blood due to unaccustomed exercise or tissue damage.

1992). The change in heart beat found by Kenny and Tarrant (1987), is different to that recorded by Eldridge (1988), who recorded that the heart bpm did not increase significantly, and concluded that transport was not a major stressor for cattle.

Table 7 : The Responses of Young Bulls to One Hours Transport:

	Resting (n=12)	1 hr Transport (n=12)
Defecation[a]	0.25±0.10	0.58±0.19
Urination[b]	0.17±0.07	1.58±0.34
Plasma creatine kinase (units l^{-1})	13.37±1.93	26.12±2.38
Plasma glucose (mmol l^{-1})	5.34±0.06	5.78±0.16
Plasma cortisol (nmol l^{-1})	5.30±0.25	59.0±0.83
Heart Rate (bpm)	73.0±3.15	104.5±3.75

[a & b events/animal/hour]
(Kenney and Tarrant,1987).

Table 6 records elevated plasma cortisol and glucose concentrations, this reflects the activation of the pituitary adrenal axis, while the elevated heart rate represents activation of SAMS. There are also signs of nervousness through the increased excretion of faeces and urine (Tarrant, 1990; Warris, 1990). This would be to the detriment of the animal's state of hydration. Mitchell *et al.* (1988), also recorded increased secretion of ACTH, this would increase the secretion of adrenocortical hormones (Espiner, 1987), which may affect the Na^+ concentration of the animal. Levantine *et al.* (1977), recorded similar results to Mitchell *et al.* (1988), noting that steers were more affected by transport than calves.

2.5.5.2.2 Changes in Blood Electrolytes in Response to Transportation Stress

The ionic changes that occur in the blood electrolyte concentration of cattle must be considered with regards to their affect on the release of hormones like ADH and

aldosterone, and how these hormonal changes affect the overall salt and water balance of the animal.

According to Mitchell *et al.* (1989), the Na^+ concentration in ECF is regulated by the mechanisms controlling water intake and output, ADH and thirst. Therefore the immediate cause of an abnormal plasma Na^+ concentration will be an abnormal water balance. Dehydration in healthy animals only occurs when drinking cannot keep pace with normal or abnormal losses. An increase in plasma Na^+ concentrations occurs due to a straight water loss, even then water should move across from the ICF to maintain plasma osmolality. In a major study by Doornenbal (1977), 1612 cattle were sampled to determine plasma K^+ and Na^+ concentrations. The results are given in Table 8.

Table 8 : The Sodium and Potassium Plasma Concentrations in Cattle Recorded Prior to Slaughter

	1971 (*n=475*)	1972 (*n=428*)	1973 (*n=262*)	1974 (*n=439*)
Plasma Na^+ mmol l^{-1}	139.2	140.9	144.85	153.98
Plasma K^+ mmol l^{-1}	6.36	6.96	7.31	8.52

(Doornenbal, 1977)

Doornenbal's results indicate that transportation has a greater effect upon the plasma K^+ concentration than upon Na^+, remembering that Ganong (1989) stated that it only needs a 1 mmol l^{-1} rise in plasma K^+ to stimulate the release of aldosterone.

In studying the effect of transportation on plasma electrolyte concentrations, the one fact that repeats itself is the variability in the results between separate trials. Atkinson (1992), studied the effect of transport on the plasma electrolyte concentrations of calves and recorded that as distance travelled increased from 0 to >280 km, neither the plasma Na^+ or K^+ concentration varied significantly to the normal plasma electrolyte concentrations, as given in Table 4. Atkinson's Na^+ concentrations were similar to the results recorded by Doornenbal (1977), but the K^+ were not. Similar trials, measuring the effects of transport and lairage on specific plasma electrolyte concentrations in cattle,

recorded plasma Na^+ concentrations that were not within the ranges given by Carlson (1989), or Doornenbal (1977).

Schaefer *et al.* (1990), in Experiment 1, recorded plasma Na^+ concentrations of 177.7 and 172.6 mmol l^{-1} in the two control groups, these concentrations decreased to 169.0 and 163.2 mmol l^{-1}, post transport. Plasma K^+ concentrations were also high in the control groups, measuring 6.7 and 7.0 mmol l^{-1}, elevating to 6.8 and 7.1 respectively following transport. Carlson (1989), stated that plasma K^+ concentrations in cattle are balanced between 3.6-5.8 mmol l^{-1}, but this figure is not supported by the results of Schaefer or Doornenbal.

Schaefer *et al.* (1992), in comparing two treatment groups, No Fluids (C), and Electrolytes (E), measured plasma Na^+ concentrations of 78.46 and 81.49 mmol l^{-1}. Schaefer also measured the plasma osmolality for the two groups as, 292.95 (C), and 288.15 (E) *mOsm/kg*, respectively. According to Carlson, (1989), if the osmolality is between 270-300 *mOsm/kg* then the Na^+ concentration should be around 132-152 mmol l^{-1}, which indicates that the plasma Na^+ concentrations measured by Schaefer are possibly inaccurate.

Table 9 : The Comparative Plasma Sodium and Potassium Concentrations Recorded by Researchers Using Cattle.

References / Groups		Weeth *et al.* 1960, mmol l^{-1}	Schaefer *et al.* 1990, (Exp. 2) mmol l^{-1}	Gortel *et al.* 1992, mmol l^{-1}	Schaefer *et al.* 1992, mmol l^{-1}
Na^+	Control	171.0	151.3±6.8	125.3±4.4	78.46
Water		-	164.6±7.0	121.8±4.4	-
Electrolyte		-	139.5±7.0	130.9±3.9	81.48
K^+	Control	-	10.2	4.7	3.64
Water		-	6.4	4.7	-
Electrolyte		-	5.1	5.1	3.64

Schaefer *et al.* (1990), in Experiment 2, and Gortel *et al.* (1992), show wide variation between their respective results, refer to Table 9. Neither Gortel, or Schaefer, make any referral to these differences in their papers.

Caution should be given to the accuracy of the results recorded by Schaefer and Gortel, firstly because Schaefer's, 1990 experiment 2, results measured the control group , (no water supplied), to have a lower Na^+, yet higher K^+, concentration than the water group. This is unusual because after 24 hours dehydration the control groups' plasma osmolality would be expected to be greater that those cattle supplied water.

Secondly, in Gortel's study, the control group, off water for 22 hours prior to slaughter, had a very low plasma Na^+ concentration, when the removal of access to water for that amount of time should have increased the plasma Na^+ to a greater amount. Finally, Doornenbal (1977), conducted his research from the same research station as Gortel and Schaefer, (Table 10), yet the electrolyte concentrations recorded by, Doornenbal, are significantly different to those of Gortel and Schaefer (Table 9).

Alternatively, if the electrolyte concentrations recorded in Table 9 are correct, and given the similarity in the methodologies used by Gortel and Schaefer, then the differences in the plasma electrolyte concentrations recorded by them could be due to the large variance in the release of adreno-cortical hormones in cattle, that was recorded by Mitchell *et al.* (1988), (Table 6).

The release of mechanisms, like the SAMS, which control the body water and electrolyte balance of an animal can be explained using 'cause and effect' reasoning. It is difficult to use this explanation to justify the results achieved by Gortel and Schaefer, due to lack of any consistent pattern in their results. This fact is further supported by variation in the homeostatic responses between the cattle (Mitchell *et al.* (1988), (Table 6).

2.5.5.3 The Effects of Feed and Water Deprivation during Transportation and Lairage

The major loss in the live weight of a cattle beast occurs in the first 12 hours of feed deprivation (Wythes, 1984, and Shorthose and Wythes, 1988). Wythes (1984), states further, that it is the hydration status of the animal that will affect its carcass weight more frequently than feed deprivation.

The supply of water to cattle prior to slaughter is important to the final carcass yield. Wythes (1980; 1983), showed that supplying water to dehydrated cattle can actually create a temporary state of over-hydration, this occurred in cattle transported 90 km. One of the observations recorded by Wythes was, that when the animals first arrived at the lairage area the animals were seen to drink in one short but concentrated session, where upon they were not seen to drink again until the next day, which is in line with the theory of Denton (1982) (*page 11*).

In transit, it is time rather than distance that affects live weight loss. The majority of the initial loss is gut-fill, lost through increased excretory behaviour (Kenny and Tarrant, 1988), and lack of feed replacement. The carcass weight lost during transport is reduced by allowing cattle access to water upon arrival (Wythes *et al.* 1985). Atkinson (1992), stated that live weight loss due to transport is unavoidable, but it is uncertain as to whether it is due to excretion, dehydration or tissue catabolism. He suggested that transportation is an exhausting process and may cause dehydration, and that, given the correct facilities, lairage will allow recovery from both dehydration and exhaustion.

Thornton and Gracey (1974) stated that early live weight loss, in transport, is partly due to excretory loss, the rest being tissue and water loss. Wythes *et al.* (1980), working out the proportion of the loss that is carcass weight, estimated that of the 68 kg live weight lost during transportation, 14 kg reflected dehydration of body tissue. Van den Heever *et al.* (1967), and Chambers (1974), recorded that 80% and 72% of live weight loss respectively was due to ingesta, the rest representing tissue and carcass weight loss.

Kent and Ewbank (1983), recorded that 6 month old calves, when transported, defecated and urinated profusely from the time of being loaded until unloaded (7-75 hours), the faeces had a diarrhoea like quality. This supports the observations by Kenny and Tarrant (1987a; 1987b), Warriss (1990), and Tarrant *et al.* (1988), who noted that defecation made the transport floor slippery, indicating that the faeces had a higher than normal water content. These results could offer support to Atkinson (1992), suggestion that transportation caused dehydration. Tarrant (1990) suggested that the increasing frequency of excretory behaviour is a sign of fear, Tarrant also recorded that both urination and cortisol peaked during movement of the vehicle.

Kent and Ewbank (1983), recorded that transported calves lost significantly more weight ($p<0001$), 84 kg, during the transport period than starved control calves over the same period, 44 kg. This supports the theory put forward by Purchas (1992), that stress accelerates weight loss. Kent and Ewbank (1983), recorded a significant rise in plasma cortisol concentration, reaching a maximum of 230.0±50.9 nmol l^{-1} two hours into the journey, while Warriss (1984), studying the effects of mixing only recorded plasma cortisol levels of 140.0±17.0 nmol l^{-1}.

Hutcheson and Cole (1986), noted that when cattle are transported there is a loss of body weight, comprised of faecal, urine and body tissue, much of which is water. They pointed out that stress causes hyperactivity of the adrenal cortex during transportation, resulting in the increased production of aldosterone. This leads to the excessive reabsorption of Na^+ and the urinary excretion of K^+. This is a different result to that shown by Schaefer *et al.* (1990), who recorded that stress as a result of transportation caused plasma Na^+ to decrease.

In summary, even under good conditions, transported cattle manifest physiological and behavioural changes that are indicative of stress. When transport conditions deteriorate, the observed physiological and behavioural changes intensify, further there are suggestions that this will accelerate the rate of carcass weight loss.

2.5.5.4 Lairage and the Supply of Fluids

In New Zealand, welfare considerations dictate under Regulation 37:1b, of the 1969 Meat Regulations, that, "the yards and the pens, together with all races appurtenant thereto, shall have an adequate number of water troughs with suitable drainage". MAF Manual 4, recommends in Section 2.12.2.1 that, " experience has shown that the areas required for stockyards and pens are, 1.70m^2 per each head for cattle, exclusive of races and alleyways". It should also be noted that this recommendation is not made in relation to a specific size of cattle beast.

The intention behind this legislation was that every animal in lairage should have an adequate area within which to stand, turn and reach available water without duress. The stocking density is only a recommendation, the actual area available to cattle per head in lairage is not policed. In England the Meat and Livestock Commission (MLC) (1974), recommended a space allowance of, 2.32 to 2.80 m^2, per animal, for loose cattle held in lairage pens. Grandin (1993), implies that cattle handled more are quieter, especially if reared indoors, which is not unusual for cattle in England. This means the MLC believe that in order for English cattle (which may already be more settled than New Zealand animals) to achieve similar aims to those laid down by MAF, their cattle need 37-65 percent more space per head than New Zealand cattle.

Wythes *et al.* (1980), showed that the longer cattle spend in lairage (up to 28 hours), with access to water, the greater is the muscle water content. Ozutsumi *et al.* (1984), in studying the effect of 48 hours of fasting on the carcass yield of cattle, recorded that supplying water did offset some carcass loss. The unexplained loss in live weight (19.8 and 20.1 kg respectively), in Table 10, may be explained by the amount of water lost via evaporation from the lungs and skin, the amount of water lost via these routes at times exceeding that lost in urine, (NRBC 1984), or via tissue catabolism (Purchas 1992; Wythes 1984). Refer to Table 10.

Table 10 : The Live Weight Loss, Excreta and Water Drunk by Japanese Black and Holstein Steers During 48-hours of Fasting.

Item		Japanese Black	Holstein
No of animals		3	3
Finished weight	(kg)	515.3±23.5	591.0±69.7
Slaughter weight	(kg)	489.0±21.5	556.3±65.8
Warm carcass weight	(kg)	303.7±20.9	325.8±34.7
Live body weight loss	(%)	5.0%	5.9%
Live-weight loss, (kg)	**A**	24.0±2.6	31.7±3.4
Faeces, (kg)	**B**	6.5±2.3	6.7±2.9
Urine, (kg)	**C**	5.9±1.2	11.8±2.9
Water Drunk, (litre)	**D**	8.2±2.0	6.9±2.5
(A+D)-(B+C) (kg)		19.8	20.1

(Ozutsumi et al. 1984)

At the time of slaughter these losses represent, 4.0% and 3.6% respectively, of the total live-weight (Table 12), which if the loss was solely due to water deprivation, would place them in a state of cellular thirst (Denton 1982). In Ozutsumi's results, it is difficult to explain the difference in ratios of urine to faeces, although part of this may have been caused by the small sample size that was used.

Gortel *et al.* (1992) reported that supplying water to yearling bulls, compared to supplying no water, over 18 hours in lairage improved the dressing-out percentage by 1.1%, increased the ECF volume, and lowered the haematocrit (%), plasma osmolality, and plasma concentrations of Na^+, K^+ and Cl^-. Schaefer *et al.* (1990) recorded results which were the opposite to those achieved by Gortel, while using a similar experimental methodology. Gortel, while referencing Schaefer *et al.* (1990), does not suggest why there was a difference.

Jones *et al.* (1992), also looking at the effects of supplying fluids to cattle while in lairage, and reported a carcass yield difference of 0.9% in favour of supplying water, after 12 hours. Suggesting that even in a short time span the supply of fluids is

important. They also noted that as the time off water increased, so did the mean hide dryness score, an indication of increasing dehydration, although there was no significant change in the scores after 12 hours.

Schaefer *et al.* (1992), using the same animals as Jones *et al.* (1992), showed increasing plasma osmolality as the time off water increased, measurements taken at 0, 12, 24,36 and 48 hours. This is a different result to Schaefer *et al.* (1990), who recorded a higher osmolality in the group supplied water compared to those not supplied water, this difference though is not referred to.

The supply of liquids to cattle is vitally important in maintaining yield, yet in its importance there is little available information related to a cattle beasts access to water while in lairage, in relation to the ideal trough size, trough height to avoid soiling, stocking density and its effect on access, palatability of potable water, or climatic effects on water requirements.

2.5.5.5 Lairage and its Effect on Blood Constituents

Blood hormone levels are affected by stress. The implications are that if an animal is unable to rest in lairage, then this may have a compounding effect upon the blood constituents of a cattle beast, and that these changes could affect the water balance of the animal.

Flores *et al.* (1992), studied the effect that transport and waiting times in lairage had on the biochemical blood parameters in cattle and found that increasing waiting times diminish the total plasma protein concentration, which was attributed to be due to the release of cortisol and catecholamines.

Flores took their blood samples post stun, which would have elevated total catecholamine concentrations (Shaw and Tume, 1992). The data recorded showed that waiting times did not effect plasma Na^+ concentrations, which ranged from 144.7 to 147.6 mmol l^{-1}. Potassium concentrations did rise, indicating the occurrence of muscle

catabolism. As the waiting time increased, the higher the concentration of K^+ in plasma. In reference to K^+, it is noted that the concentrations fluctuated between the three trial groups, the groups recorded the following K^+ concentrations, control group 5.3±0.3 mmol l^{-1}, group 2 (12-24 hrs waiting time) 4.3±0.7 mmol l^{-1}, and group 3 (48-72 hrs waiting time) 6.2±1.0 mmol l^{-1}. The effect of this may be due to the stimulation of the adrenal cortex, releasing aldosterone, thereby increasing the secretion of K^+, before diminishing in its effect over time, as explained by Espiner (1987).

Flores *et al.* (1992) concluded that while the actual changes in K^+ and Na^+ concentrations were insignificant, the changes in the ratio of Na^+ to K^+, over time, indicates significant alteration in the homeostasis of cattle, in stressful situations.

In the work by Flores *et al.* (1992), the animals used were fed and watered while in lairage, and no stocking density is given. The assumption is that the cattle were held at a low stocking density similar to that recommended by the MLC. This may have allowed the cattle greater relaxation while in lairage, suggesting that at higher stress levels there may be greater alterations in blood constituents, while in lairage.

2.5.5.6 The Provision of an Adequate Rest Period for Cattle During Lairage

The question to be considered, when discussing the effects of lairage upon cattle is, "Is it rehabilitative, do the animals actually get a chance to rest and recover from the effects of transportation, fatigue and dehydration ?"

In New Zealand, the time cattle spend in lairage prior to slaughter is controlled by several factors, these being the animal meeting the pre-slaughter requirements of the veterinary inspection, the emptying of gut contents overnight to lower the occurrence of contamination during evisceration, and ensuring the continuity of supply of cattle into the knocking box. These three factors may often control the way stock are handled in lairage ahead of perhaps less economically rewarding methods. While lairage is referred to by researchers as a place of rest and recovery, little work in New Zealand has been done to actually prove this.

Cockram (1990) stated that the minimum resting time to improve meat quality is 6 hours, and also that some aspects of the management of cattle, and the environment within lairage, may impair the ability of animals to actually rest. van Logtestijn and Romme (1981) suggested that under a commercially realistic period in lairage, an animal is unlikely to be able to recover from the effects of handling and transport.

An animal can be considered to be at rest when it is in a physical state to allow for possible sleep and relaxation. Tarrant (1988), stated that cattle are notoriously inactive, normally only moving to find feed, water and shelter. Cockram (1990) studied the way behaviour is affected in lairage and noted that cattle do not often lie down while on a concrete floor at higher stocking densities. The repression of an animal's ability to rest and/or ruminate maybe considered to be a stressor (Grant Guilford, personal communication).

The arrival at a lairage area is likely to be a novel stimuli for cattle, and therefore can be considered to be a short term stressor (Stephens 1980), and the nature of the lairage environment is likely to affect the ability of the animal to rest. Eldridge (1988), recorded that cattle left in a more noisy, and visually active part of the lairage area had a significantly higher bruise score, and were more active.

Several researchers have reached conclusions about the behaviour of cattle in lairage, these are as follows. The ability of an animal to rest is also controlled by the social stability of the group (Bartos *et al.* 1993). Fabianssion *et al.* (1984), pointed out that in Sweden keeping bulls in individual pens lowered their stress levels. Wythes *et al.* (1985), concluded that when cattle are disturbed while in a strange environment they may not drink from unfamiliar troughs. Tarrant *et al.* (1988), showed that as stocking density increased, so to did carcass bruise scores during transport. Stocking density, therefore, may have the same effect in lairage.

Rest in lairage is important, because if the animals are unable to relax, then homeostatic mechanisms that increase the concentration of hormones affecting salt and water balance

may continue to function at above normal levels, to counter the abnormal environment. Thereby still affecting the potential dressing-out percentage.

2.5.5.7 The Use of Oral Rehydration Therapies in Lairage

In the preceding text it has been suggested that, biochemical changes associated with taking cattle from the farm to slaughter are physiological in origin, therefore they are potentially treatable. Schaefer *et al.* (1990), observed in Experiment 1, that even moderate forms of imposed stress was sufficient to invoke changes in blood electrolyte levels.

Due to these changes Schaefer *et al.* (1990), introduced an electrolyte treatment into Experiment 2. The electrolyte solution used contained, (wt/vol): 0.02% Sodium Chloride, 0.02% Potassium Bicarbonate, 0.01% Magnesium Sulphate and 0.005% each of the following amino acids: alanine,lysine, phenylalanine, glutamate, trypotophane, methionine, leucine, isoleucine and valine. The inclusion of amino acids was to improve the rate of absorption of sodium and water in the intestine (Blood *et al.* 1983). Refer to Table 12 to see the formula in mmol l^{-1}.

According to the results achieved by Schaefer *et al.* (1990; 1992) and Gortel *et al.* (1992), the supply of an electrolyte or an electrolyte-glucose solution prior to slaughter would improve potential dressing-out percentage by 0.8 to 3.0 points. The implication of this is that cattle when slaughtered may be dehydrated by these amounts due to the effects of pre-slaughter stressors and feed deprivation, and the consumption of an electrolyte solution will improve the retention of ICF and ECF in the meat to a greater degree than supplying pure potable water.

In Gortel's conclusion it is suggested that the rate of trans-membrane movement of water appears to be enhanced if the water is accompanied by ions. Gortel also suggests that ions and water may be sequestered into cells in response to stress. In summary, Gortel states that, "the introduction of an electrolyte solution that is similar in composition to the interstitial fluid appears to be most beneficial to preserving the

integrity of the fluid compartments". Yet their own formula is substantially different to the composition of interstitial fluid (Ganong, 1989), (Refer Table 11).

Mitchell *et al.* (1989), disagrees with Gortel, suggesting that the usefulness of oral rehydration therapies (ORT) is not to compare the formulas with plasma, but with the concentration and formulation most likely to promote intestinal uptake of salt and water. In practical terms this is approximately, 100 mmol l^{-1} of saline and 20 g l^{-1} glucose, as is the World Health Organisations (WHO) treatment for human cholera (Mitchell, 1983). A point to note is that the treatment prescribed by Gortel *et al.* (1992) is supplied ad lib through a water supply system, while the ORT suggested by Mitchell (1983), is supplied in fixed amounts.

ORT fluids are designed to cause the absorption of Na^+ and water through the action of the carrier system, that brings Na^+ and glucose simultaneously into the cells from the intestinal lumen. This 'co-transport' system remains active even when the absorption of salt and water, by the villus cells, has been impaired by disease-causing micro-organisms, which disrupt intestinal function (Hirschhorn and Greenough, 1991). In healthy cattle awaiting slaughter, the action of the villus cells should not actually be impaired. The advantage of using ORT fluids is that it is an effective route, (by mouth), the application is simple and economic, and there is no need for a sterile solution.

The primary objective of fluid therapy is the restoration of undistorted renal function, chiefly by the correction of deficits in circulatory volume (Mitchell, 1983). In horses the supply of electrolytes and water is intravenous, the aim to accelerate the rate of recovery of the animal after a race or intensive training(Cohen *et al.* 1993).

Wood (1994), using ORT fluids on cattle, indicated a 1% increase in carcass weight about 50% of the time, suggesting an equal number of non response trials. Wood (1994) used the ORT fluid's predominantly on cattle during recovery from transport, the aim being to reduce the effects of live-weight shrink, and to stimulate the appetites of the cattle introduced into feedlots. The electrolyte solution was being supplied at a hypertonic concentration.

Table 11 : ORT Formula's Compared to the Electrolyte Solutions Used by Schaefer and Gortel.

All measures mmol l^{-1}	Na	K	Cl	HCO_3	Mg	SO_4	Glucose %
ORT solutions							
Ionalyte	155	12	106	61	0	-	0
IRT	140	10	103	74	0	-	0
Electrosol	138	8	83	68	0	-	2.5
09% NaCl (isotonic saline)	155	0	155	0	0	-	0
Volac anti-scour	27	5	21	11	Mg	-	0.75
Daltons	42	26	39	21	0	-	5.0
McSherry's Sol (Bal. elect. sol.)	138	12	100	0	5	-	0
Wood.T (1994)	58	1	3.5	0.5	-	-	0.12
Ref: Mitchell et al. 1989; Blood et al. 1983							
Schaefer *et al.* (1990)	3.5	2	3.4	2	0.8	0.8	0
Schaefer *et al.* (1992)	3.5	2	3.4	2	0.8	0.8	5.0
Gortel *et al.* (1992)	17.4	10	16.9	10	4.1	4.2	5.0
Interstitial Fluid (Ganong, 1989)	143	5	106	27	3.0	-	-

ORT solutions usually contain Na^+, Cl^-, K^+ and Ca^{2+}, at a concentration similar to ECF electrolyte composition. These balanced electrolyte solutions are considered safe and can be used in large quantities without creating electrolyte disturbances (Blood *et al.* 1983). They can be used for most situations involving dehydration, moderate acidosis or alkalosis, and moderate electrolyte imbalances. As dehydration is not usually detected up till 5% of body weight has been lost, most ORT's are aimed at restoring deficits greater than this. Table 11 gives the formulae to several ORTs that are available.

The principle of fluid and electrolyte therapy is to prevent, or minimise, dehydration and electrolyte loss, whenever possible. This means the provision of an adequate supply of water, adequate drinking space, a continuous supply of salt and necessary minerals (Blood *et al.* 1983).

2.6 SUMMARY

The loss of carcass weight in cattle can occur due to either a loss of body water and/or catabolism within the muscle and fat cells during the marketing of cattle to slaughter. Stress has the potential to accentuate these losses. The live weight of an animal is made up of around 60% water divided into two areas, extracelluar fluid and intracellular fluid. These fluids are held in a state of osmotic equilibrium, separated by a membrane which allows water to move across it easily. The major cation in ECF is sodium and for ICF potassium. These are held separate by an energy requiring Na^+-K^+-pump. In a 'normal', healthy animal the concentration of body salts is held within narrow limits by a variety of mechanisms.

Changes in ECF volume dictate major responses to homeostatic control mechanisms. This is because ECF is more accessible to insults from environmental stressors that may cause dehydration or water loss. A reduction in body water causes the release of ADH. ADH slows the excretion of water through the kidneys and so protects the ECF and ICF volume. Water balance following a deficit can only be achieved through water uptake.

The renin-angiotensin system affects sodium balance and effective circulating volume through vasoconstriction and by stimulating the release of aldosterone. The release of renin is often in conjunction with the sympathetic nervous system. A-II is a potent pressor, it also acts to stimulate secretion of ADH. Aldosterone affects ECF volume through its regulation of sodium and potassium, increasing Na^+ absorption and K^+ excretion in the kidneys. With aldosterone, its major controlling factor is A-II via the release of renin, but ACTH also controls the release of aldosterone.

Other forms of stress, apart from dehydration cause the release of patterned response systems to defend the internal milieu of an animal. One being the SAMS, responding to 'fight or flight' elicited stress responses as well as hypovolemic stress, releasing ACTH. ACTH has an impact on the release of hormones from the pituitary gland. This means it also affects ECF volume and sodium status. Prolonged stress responses via the

release of ACTH has led to the development of over-riding mechanisms to stop the salt and water balances going outside the narrow fields they are held in.

This review has concentrated upon many documented physiological changes which occur in cattle during their interaction with stressors prior to slaughter, and has focused primarily on blood electrolytes and metabolites. The changes that occur with regularity are, increased blood lactate and glucose concentrations, elevated ACTH and cortisol levels in the blood, and increased heart rates apparently due to stimulation of the internal medulla. Notable in these results is the large variation between cattle in the level of secretion of cortisol and ACTH. This is suggested by Grandin (1993) to be a result of variation in animal temperament, often due to previous handling experiences of the animal.

Tied into these responses is the secretion of hormones, primarily aldosterone, ADH and renin. These control the salt and water balance and are secreted as the animal adjusts blood flow in order to cope with stressors, excessive exercise, or dehydration. The inferences made by Schaefer *et al.* (1990) and Gortel *et al.* (1992), are that these changes lead to an imbalance in the internal environment of an animal that activates homeostatic mechanisms, but because they are physiological in origin they are potentially treatable by supplying an electrolyte solution.

Most research on the use of electrolyte solutions has focused on oral rehydration therapies, where animals being treated are diagnosed clinically dehydrated. This is primarily due to diseases, like diarrhoea, which destroy the ability of an animal to defend itself against water and salt imbalances. An animal being treated with an ORT should also be placed in a low stress situation, to allow for an improved rate of recovery.

Wood (1994, personal communication), recorded that their electrolyte solution (refer Table 12) accelerates the recovery period after long distance transport, and also limits live weight loss. Other researchers suggest that, a loss in carcass weight can be avoided

through the supply of water in lairage, combined with improved management, and animal welfare practices.

Schaefer and Gortel both indicate that there are benefits, through the supply of their respective formulations, to cattle prior to slaughter. Gortel and Schaefer both infer that supplying a dilute electrolyte solution to cattle prior to slaughter needs to be tested under commercial conditions. The following research will attempt to achieve this goal.

CHAPTER THREE

MATERIALS AND METHODS

3.1 AIMS AND OBJECTIVES

The aim of the following research was to establish the following:

Experiment One : Whether the water consumption of a cattle beast in lairage is affected by either stocking density and/or climate, while being held in lairage.

Experiment Two : Whether the supply of an electrolyte solution, during lairage could improve the dressing-out percentage of an animal. This was done by testing null hypothesis, to 95% significance, that:

H_o : $N_1 = N_2$,that the mean carcass yield from cattle supplied an electrolyte solution was no different to the mean carcass yield of cattle supplied water, while in lairage, prior to slaughter.

Experiment Three : The Palatability Trial. The aim was to establish whether cattle found the electrolyte solution palatable.

Multigro : A brief background into Multigro is established, the diluted Multigro solution that was to be supplied to the cattle was examined to discover how it would behave while in lairage.

3.2 COLLECTION OF SAMPLES

The research was conducted at Manawatu Beef Packers (MBP), located in Feilding. It is an export licensed Meat Works (one beef chain), capable of killing 500 head/day in

a double shift. The research was conducted in a manner that mirrored, as closely as possible, the handling and management of the cattle under commercial conditions. Full co-operation was given by the employees and management at MBP.

3.2.1 The Plant Lairage Area

The cattle lairage area for the trial consisted of:

(1) A parallelogram shaped pen, measuring 3.5m by 6.6m, total area 23.10m^2.

(2) Access to water consisted of a semi-circular trough, with 1.4m^2 of available water surface area, permanently fixed to the west side of the pen, 1m along from the left hand corner. The top of the trough was 0.9m from the ground.

(3) The pen floor was concrete, with a diamond-shaped pattern pressed into it to improve traction.

(4) The cattle were held under cover, with internal diffuse lighting provided at 150 lux.(MAF Manual 4. 2.12.2.7)

(5) Pen fencing consisted of 4.5cm steel piping, rails placed 20cm apart, allowing minimal physical contact with stock in neighbouring pens.

3.2.2 Pre-Slaughter Preparation

(1) The pen was washed with a high pressure spray and the trough was cleaned prior to cattle being placed in the lairage pen.

(2) Once cattle were housed in the lairage area they were not moved or handled directly until it was time to slaughter them.

(3) Prior to slaughter the cattle were removed from the pen, washed in a still water trough. The depth generally came half way up the flank of the cattle. A stock-man then sprayed the top half of the cattle from a nearby walkway.

(4) On average it took 30 to 45 minutes from the time the animals left their pen until the last animal was killed (Henry Meads, Stock Yards Manager, MBP, 1994).

3.2.3 The Supply of Stock

A total of 189 cattle were used during the course of this study. These were allocated according to Table 12 :

Table 12 : The Number of Cattle That Were Used in Each of the Three Trials in Experiment Two.

	Experiment 1	Experiment 2		Experiment 3
		Water	Electrolytes	
Steers	83	27	28	8
Bulls	45	29	29	0
		56	57	
Total	**128**	**113**		**8**

(1) The results from the cattle in Experiment 2 that were supplied Water only was compiled and used as data in Experiment 1, which is why the total of the cattle used in Experiment 1,2, and 3 is greater than 189.

(2) Cattle used in Experiment 2 were supplied from the Manawatu district, the main criterion being the availability of an accurate on-farm weighing system. The 113 animals were grouped into 4 sample groups. (refer Table 13)

Each sample group was divided in two, depending upon which fluid they were supplied : Water (W) or an Electrolytes (E) solution.

Table 13 : The Sample Size and Time Spent Travelling by Cattle Used in Experiment Two.

Trial No.	1		2		3		4	
Sample Size n=x	28	W = 14 E = 14	25	W = 12 E = 13	30	W = 15 E = 15	30	W = 15 E = 15
Travel Time (Minutes)	20		20		20		45	
Hrs. in Lairage	23.5		23.5		23		19.5	

3.2.4 Experimental Design

3.2.4.1 Experiment One :

The aim of Experiment One was to gather information on the water consumption by cattle in lairage (to establish whether there is a demand for fluids). Criteria for the selection of the cattle was minimal. The lairage management would make a pen of cattle available, these would be held over-night, and their water consumption measured from the time the animals entered the lairage area until their removal for slaughter.

3.2.4.2 Experiment Two :

The aim of Experiment Two was to establish whether, under commercial meat plant handling and management conditions, the supply of a dilute electrolyte solution to cattle prior to slaughter offered any financial benefits as seen by Schaefer *et al.,* (1990); Gortel *et al.,* (1992) and Wood (1994, Private communication).

(1) Four separate trial groups were used in Experiment Two (groups are numbered 1 to 4). Each group was weighed on the farm of origin immediately prior to transport to the meat plant.

(2) Each trial group was randomly divided into two sub-groups (sub-group 1=Water, sub-group 2=Electrolyte). Group No. 1 and 3 were divided into their sub-groups on the farm of origin. Group No. 2 and 4 were divided into their sub-groups as they were unloaded at the meat plant. Drafting of the cattle was controlled only by breed, to ensure that the impact of the breed was minimised, thereby removing any bias that might be introduced.

(3) The farmers were free to choose the transport operator and stocking density on the truck.

(4) Once in the Plant lairage area the two sub-groups were allocated separate pens next to each other. These two groups were treated and handled under normal operating conditions, except that one group was given water *ad lib* and the other an electrolyte/glucose solution, supplied to them via the trough system. (Refer to 'Design of Fluid Supply System')

(5) On the following day the animals were removed from their pens, washed, moved to the knocking box, and stunned by an operator using a Captive bolt.

(6) Cattle plant live-weights were recorded after hoisting, but before exsanguination. All carcasses received the standard carcass trim, as laid down by the New Zealand Meat Producers Board, 1992, Appendix 2. The warm carcass weight was then recorded immediately prior to the carcasses entering the chillers.

(7) The following data was collected :

- **(a)** On farm live weight.
- **(b)** Live weight prior to slaughter.(Plant weight)
- **(c)** Hot carcass weight.

(d) Mean temperature during the day and night cattle were held.

(e) Average fluid consumption per head.

(f) Stocking density while in lairage.

3.2.4.3 Design of the Fluid Supply System:

(1) Two 420 litre heavy duty black alkathene tanks were placed upon separate steel mesh platforms above each holding pen, and secured to the overhead walkway in the lairage area.

(2) One tank contained potable water supplied by MBP, the other contained the electrolyte Multigro, diluted to a concentration of:

-: 20ml/litre water for trial 1.

-: 10ml/litre for water trials 2,3, and 4.

(3) The existing lairage trough system in the lairage area was used to supply the fluids to the cattle. Two troughs, in separate pens, were isolated from the main plant water supply and attached to the respective over-head tanks.

(4) The supply of liquid into the troughs was controlled by a ball-cock valve.

(5) Total fluid consumption per pen was measured via the use of a dip stick, the fluid level in the tanks was measured at the start and end of each trial, the difference being equal to the amount of fluid consumed.

Figure 2 : Diagram One shows the design of the fluid supply system.

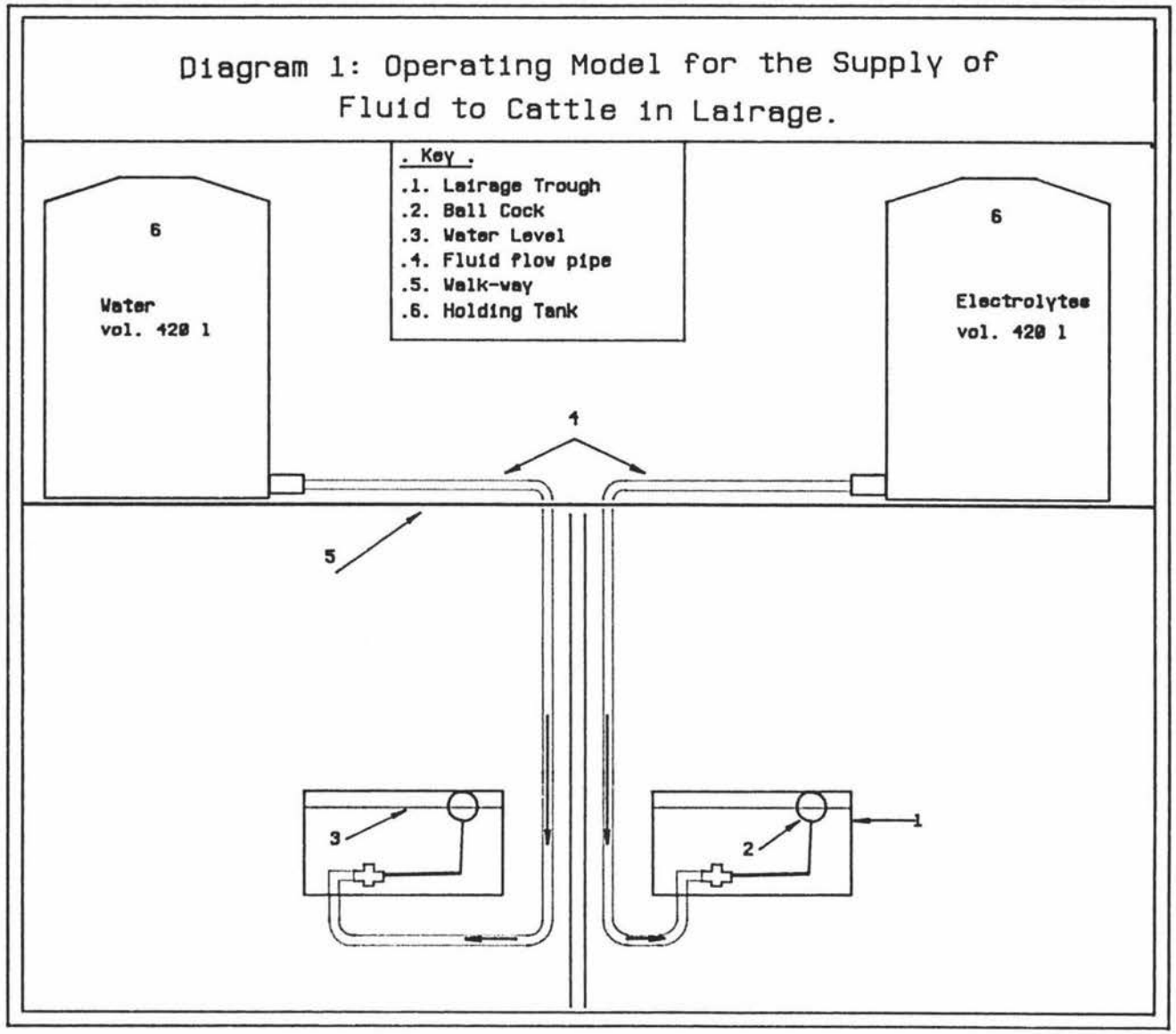


Diagram 1: Operating Model for the Supply of Fluid to Cattle in Lairage.
. Key .
.1. Lairage Trough
.2. Ball Cock
.3. Water Level
.4. Fluid flow pipe
.5. Walk-way
.6. Holding Tank
6
Water
vol. 420 l
6
Electrolytes
vol. 420 l
4
5
3
2
1

Figure 2 :

3.2.5 Experiment Three : Palatability Trial

A palatability trial was run at the end of the research conducted at MBP to establish whether cattle preferred the dilute electrolyte solution to water.

Eight 12-14 month old Friesian steers were split into three groups: these were supplied with either water only ($n=2$), or a choice of water or the electrolyte solution ($n-4$)(diluted to 10ml/L), or just the electrolyte solution ($n=2$). The results were divided into four groups:

(1) Water only,
(2a) Water drunk before Multigro solution,
(2b) Multigro solution drunk before water,
(3) Multigro only.

The cattle were held for 48 hours total, and fed with hay *ad lib* in order to increase the fluid intake of the cattle. Fluid consumption was measured after 24 and 48 hours. Results are in Table 28 and Figure 8.

3.2.6 Analysis of Multigro

The aim of this section was to firstly obtain a detailed composition of Multigro and secondly assess what happened to the solution when left standing in its diluted form for a period of time.

(1) Two samples of Multigro were sent to the New Zealand Pastoral Agricultural Research Institute Limited (AgResearch) to be analyzed using the 'elemental analysis of samples by plasma emission spectrometry. The samples were taken from two separate 20 litre drums of Multigro, in its concentrated form. The first drum had been open for two weeks, the second drum was opened the morning that the tests were conducted.

(2) In the second test Multigro in its diluted form (10ml/l) was left standing in one of the 420 litre holding tanks, in the lairage area, for ten days, the aim to measure the build up of micro-organisms in the solution.

A plate smear was made of the solution using plate count agar, the plate smear was then held in an incubator, for 2 days, at 30°C. The resulting bacterial growths were placed upon slides and stained, and the individual organisms were identified under a microscope by Massey University microbiology staff.

3.2.7 Statistical Analysis

The data was compiled using the spread sheet package Quattro, Version 5 (Copyright 1993, Borlands International Ltd.). The statistical analysis package SAS (Statistical Analysis Systems Institute, 1985., SAS institute Inc., Cary, N.C., USA) was used to analysis the raw data.

The SAS analysis of variance module was used to assess the significance of the following variables on water consumption (dependent variable): hours in lairage (Hour), the daily maximum temperature (C°), the stocking density (hd/m^2) ,and the combined interaction of Hour and C°.

In experiment 2, the raw data was summarised in Table 21, the dressing-out percentages from the three trials were compared against each other (water *Vs* electrolyte) to measure the significance of any difference between the two means, this was then repeated on each individual trial. The analysis was then repeated using co-variate analysis, to remove possible bias due to differences in on farm live weights between the two groups (Water *Vs* Electrolyte). The resulting P-value was used to measure the probability of accepting the Null hypothesis correctly.

CHAPTER FOUR

RESULTS

4.1 ANALYSIS OF MULTIGRO

4.1.1 Introduction

The sample of Multigro, supplied by Coast Biologicals, was analysed by the New Zealand Pastoral Agricultural Research Institute Limited (AgResearch). Their analyses, together with the data supplied with Multigro from Coast Biologicals Ltd., has been presented in Table 14 and Appendix 3. As can be seen in Table 14, there were some major discrepancies in the two analyses.

4.1.2 The Electrolyte/Glucose Solution

The AgResearch analytical results were used to formulate the electrolyte solution used for all trials conducted in this study, and is the one referred to throughout this thesis. The values given in Table 14 are the mineral concentrations that were supplied to the cattle. To achieve these values the concentrated electrolyte solution was diluted with water at a ratio of 1:100 or 10ml/litre. Double these values were used to produce the concentrations at 20ml/litre.

Table 14 : The Mineral Ingredient Analysis of Multigro: No. 6345, Diluted to 10ml/litre.

Element	Multigro analyzed by AgResearch mmol l^{-1}	Multigro analyzed by Coast Biologicals mmol l^{-1}
Sodium	**18.0**	6.9
Chloride	**17.8**	6.8
Potassium	**2.6**	1.0
Bicarbonate	**2.6**	1.0
Sulphur	**1.1**	0.4
Magnesium	**2.1**	0.4
Calcium	**0.5**	0.5
Glucose[1]	**0.2**	0.5
mOsm/kg[2]	***45.0***	-

1 Glucose concentration measured using YSI machine, Model 27a.(Serial 206; Yellow Springs Co., Inc. Yellow Springs, Ohio.)

2 Osmolality measured using Advanced Digimatic Osmometer, Model 3D2. (Serial No. 35986C, 1000 Highland Ave./ 617-449-3000, Needham Heights, Massachusetts.)

4.1.3 Reaction of Multigro in Lairage

(1) Multigro at 10ml/litre had a pH of 6.7.

(2) When left standing for 10 days a pungent sulphur smell developed, this was assumed to be due to the production of hydrogen sulphide by anaerobic bacteria in the bottom of the 420 litre holding tank.

(3) A plate smear test was completed, the developing bacteria were identified as *micrococcus, gram -ve rods (pseudomonas), gram +ve rods (clostridium) and bacillus*. These bacteria are recognised as air borne contaminants found in dusty areas, typical of a lairage situation.

(4) Multigro in its concentrated form uses the preservative p-hydroxybenzoic acid (sodium salt), resulting in a sodium chloride (NaCl) concentration of 108g/litre (10%). At this concentration the NaCl would inhibit the growth of the air borne organisms identified. The dilution of the Multigro concentrate (100x) creates a bacteriological media concentration that no longer inhibits the growth of these organisms.

4.2 EXPERIMENT ONE

4.2.1 Introduction

A total of 128 cattle were trialed to assess the effect that temperature on the day of the trial (°C), duration (hrs), and stocking density (kg/m^2) had on the water consumption of cattle whilst in lairage. In the second part of experiment 1, cattle from groups 4,5 and 6 [water and electrolyte pens (*n=83*)] were used to determine the impact that live weight lost between the farm and slaughter had upon the dressing-out percentage.

4.2.2 The Effect of Stocking Density, Temperature, and the Duration in Lairage Upon Water Consumption

Table 15 recorded the data collected from the nine trials conducted in Experiment 1. Table 16 provides a summary of the data from Table 15. Points to note about Table 15 include, the variation in the holding time of the cattle trialed, and also the starting and finishing times of the trials. These inconsistencies could not be avoided, and were one of the costs of fitting this trial into the daily operation of a commercial abattoir. Table 17 is a summary of the regression tables in Appendix 4, and records the significant effect the independent variables had upon water consumption.

Table 15 recorded that the average amount of water consumed per trial was 13.14 litres per head (L/hd) with a range of 1.4 to 29.9L. A significant observation from Table 15 was the effect that the duration in lairage had on water consumption.

Table 15 : Experiment 1 : The Effects of Stocking Density, Duration, and Temperature Upon the Fluid Consumption of Cattle in Lairage.

Group Number	Hours in Lairage	Climate (C°)[1] (Date) Low	High	Water Groups. Water drunk per head. L	Stock Density kg/m²	Stock Density hd/m²	Cattle Number (Sex)	Electrolyte Groups. Elect. drunk per head. L	Stock Density (kg/m²)	Cattle Number (Sex)
1	24.0 (11am-11am)	18/1/94 14.5	21.0	16.3	441.6	1.54	15 (Steers)	n/a	n/a	n/a
2	18.0 (2pm-8am)	25/1/94 9.5	20.5	13.9	404.8	1.35	17 (Steers)	n/a	n/a	n/a
3	21.0 (9am-6pm)	27/1/94 6.5	23.0	12.2	337.7	1.77	13 (Steers)	n/a	n/a	n/a
4	23.5 (10.30am-10am)	15/2/94 10.5	25.5	29.9	333.5	1.65	14 (Bulls)	21.7	331.7	14 (Bulls)
5	23.5 (9.30am-9am)	2/3/94 9.5	18.5	16.7	338.1	1.92	12 (Steers)	15.6	339.6	14 (Steers)
6	23.0 (11am-10am)	15/3/94 14.0	19.5	19.0	309.5	1.54	15 (Bulls)	11.0	298.6	15 (Bulls)
7	19.5 (12pm-7am)	28/4/94 7.0	19.0	1.4	401.3	1.54	15 (Steers)	0.0	397.0	15 (steers)
8	17.5 (12pm-5.30am)	3/5/94 6.5	19.0	1.9	276.0	1.44	16 (Bulls)	n/a	n/a	n/a
9	21.5 (12pm-9.30am)	6/5/94 5.5	16.0	7.0	289.4	2.1	11 (Steers)	n/a	n/a	n/a

.1. *Source : Manawatu Evening Standard.*

n/a *non-applicable, as no cattle were trialed.*

Table 16 : Statistical Data Taken From Table 14, Related to Factors Effecting the Water Consumption of Cattle During Lairage.

Variable	n=x	Mean	Standard Deviation	Minimum	Maximum
Water Consumption, Litres (W)	9	13.14	8.4	1.4	29.9
Hours Spent in Lairage (Hrs)	9	21.27	2.32	17.5	24.0
Daily Temperature (°C)	9	20.75	2.59	16.0	25.5
Socking Density in Lairage (hd/m^2)	9	1.64	0.23	1.35	2.1
Combined Effect of Hrs. and °C.	9	-	-	-	-

The duration in lairage ranged from 17.5 to 24.0 hrs, the average time in lairage being 21.27 hrs. (Table 16). As the duration in lairage increased so to did water consumption ($p<0.05$) (Table 17).

The mean daily lairage temperature was 20.75°C, with a range of 16.0 to 25.5°C (Table 16). In January water consumption averaged 14.1 L/hd, and the mean temperature was 15.8 °C. In February/March this increased to 21.8 L/hd, and the mean temperature was 16.25 °C, water consumption then dropped significantly in late April/May to 3.4 L/hd, the mean daily temperature during this period was 12.2 °C. These results point to a relationship between the daily mean temperature and water consumption.

There were however anomalies to this temperature versus water consumption relationship. For instance, group 9 consumed 9 l/hd when the mean daily temperature was 10.75°C. Whereas groups 7 and 8 recorded substantially lower water consumption even though the mean daily temperatures were higher. This difference may have been caused by the longer time in lairage experienced by group 9 (21.5 hrs) compared to 19.5 and 17.5 hrs. in lairage experienced by groups 7 and 8 respectively.

Table 17 : The Significance of the Hours Spent in Lairage, Maximum Daily Temperature, and Stocking Density, Upon the Water Consumption of Cattle During Lairage[a].

Dependent Variable : Water Consumption (W)

Independent Variable	Equation $Y_{ij}= \mu i + \beta x_{ij} + e_{ij}$ [b]	p
Hours Spent in Lairage (Hrs)	$Y_{ij}= -41.52 + 2.57(Hrs_{ij}) + e_{ij}$	0.033
Maximum Daily Temperature (°C)	$Y_{ij}= 2.14 - 30.22(°C_{ij}) + e_{ij}$	0.054
Stocking Density (hd/m^2)	$Y_{ij} = 3.02 + 8.157(hd/m^2_{ij}) + e_{ij}$	0.84
Combined Effect of Hrs. and °C.	$Y_{ij} = -66.13 + 2.12(Hrs_{ij}) + 1.69(°C_{ij}) + e_{ij}$	0.015

a : *Complete Analysis of Variance tables for Table 16 are in Appendix 4.*

b : $Y_{ij}=\mu i+\beta x_{ij}+e_{ij}$ *(Ref. Snedecor and Cochram, 1967)*

Y_{ij} = *the observation on individual j from group i.*
μi = *the mean of the population that corresponds to the* i^{th} *group.*
βx_{ij} = *the slope of the regression line, specifies the change in Y per unit increase in x.*
e_{ij} = *a random residual error unique to the individual observation, assumed to be normally distributed with mean zero and variance* σ.

Unexpected water consumption results were also seen between groups 2,3, and 5, where group 5 experienced lower temperatures but a longer holding time (14°C, 23.5 hrs.) and consumed 16.75 L/hd of water, compared to groups 2 and 3 which drank less water even though the daily mean temperatures were higher (Grp. 2 = 15.0°C, 13.9 L/hd; Grp. 3 = 14.75°C, 12.2 L/hd). Both these groups experienced shorter holding periods of 18 and 21 hrs. The importance of this combined influence is reflected in the significance of temperature and duration upon water consumption. As these variables increased so did water consumption ($p<0.025$).

The third anomaly was seen between group 1 and 6, this trend was opposite to the above two examples in that group 1 experienced a higher temperature to group 6, 17.75 vs 16.75°C, and also experienced a longer duration in lairage, 24 vs 23 hrs., yet group 1

drank less water, 16.3 vs 19.0L. The reason for this difference is not clear from the data collected.

The effect stocking density (hd/m^2) had upon water consumption was not significant. The stocking density ranged from 1.35 to 2.1 hd/m^2. In some cases the higher stocking densities may have affected water consumption, e.g. 1.35 hd/m^2 drank 13.9L, compared to 1.54 hd/m^2 drank 16.3L (January trials). In other cases a reverse effect was recorded, e.g. 1.54 hd/m^2 drank 19.0L, and 1.92 hd/m^2 drank 16.7L (March trials). A multiple regression model was used to remove the effect that temperature and duration may have played in affecting the impact of stocking density, but this did not alter the significance of stocking density on water consumption.

Table 18 : Summary of the Live Weight Lost Between the Farm and the Knocking Box in Relation to its Affect on the Dressing-out Percentage, taken from Trials 1 to 3.

	Trial 1		Trial 2		Trial 3	
	W	E	W	E	W	E
Mean Live Weight Lost (kg)	23.6±9.6	11.5±7.9	47.4±14.6	50.4±19.1	31.3±9.2	34.2±12.3
Mean Dressing-out Percentage (%)	55.5±0.02	54.6±0.02	52.5±0.01	52.4±0.02	49.8±0.02	49.5±0.01

Raw data in Appendix 1.

4.2.3 The Significance of Live Weight Loss Upon the Dressing-out Percentage

The aim of this part of the study was firstly to establish the relationship between dressing-out percentage (Dr%) and the live weight lost (LWL) by cattle between the farm and the knocking box, and secondly to see whether there were any differences between cattle supplied with water as compared with cattle supplied an electrolyte solution. The summary of these results is provided in Table 18.

Table 18 shows that there was no consistent trend to indicate that the mean live weight lost affected the dressing-out percentage for cattle supplied either water or an electrolyte solution. In Trials 2 and 3 cattle permitted to drink only water whilst in lairage lost slightly less live weight compared to cattle with access to the electrolyte solution. The water groups also consumed more fluid than the electrolyte groups. Though there was a difference in the LWL between the water and electrolyte groups (Trial 2 and 3), this difference was not significant. Statistically the mean LWL and dressing-out percentages for the water and electrolyte groups in Trials 2 and 3 are the same.

In Trial 1, cattle with access to water lost over double the amount of weight that cattle with access to electrolytes lost (23.6 vs 11.5 kg). The cause of the difference in Trial 1 is difficult to explain given that the cattle supplied water had similar on-farm live

weights to the electrolyte group, 550.6 vs 547.3 kg (Table 24) and drank 8.3L more fluid than the electrolyte group (29.9 vs 21.6 L/hd).

Table 19 : Demonstrates the Range in the Live-Weight Lost and the Dressing-out Percentages, and Shows Examples of Cattle With Similar Carcass Weights that have Different Farm Weights, Within Each Trial.

Trials	Tag No.	Farm Wgt. (kg)	LWL (kg)	Cass Wgt. (kg)	Dr% (%)
Trial 1	7	458	7	235.0	**51.3**
	n/a	526	17	311.0	**59.1**
	43	586	17	313.8	53.5
	6	576	**41**	304.0	52.8
	34	574	**2**	314.2	54.1
	20	558	29	288.4	51.7
	23	530	7	292.0	55.1
Trial 2	22	644	**77**	323.8	**50.3**
	10	637	**7**	368.2	**57.2**
	8	710	66	367.0	51.7
	19	644	38	366.0	53.7
Trial 3	550	434	35	203.6	**46.9**
	515	482	25	255.8	**53.1**
	501	468	**9**	244.4	52.2
	522	528	**59**	270.0	51.1
	526	489	46	239.6	49.0
	541	475	43	239.6	50.4
	511	437	28	240.8	51.8
	533	466	40	239.2	47.3

Characters in bold depict the range in the data for that trial.
Data collated from both Water and Electrolytes groups in each trial : Appendix 1.
n/a : no tag number.

In Table 19 the data shows that within each trial there is a significant range in the LWL, Trial 1 = 2 to 42 kg, Trial 2 = 7 to 77 kg, and Trial 3 = 9 to 59. Table 19 also demonstrates that while there are differences in the on-farm live weights and in the LWL, it does not necessarily follow that there will be differences in the carcass weights. For example in Trial 1 cattle numbered 20 and 23 had a 4 kg difference in their carcass

weight loss, yet had 28 kg difference in farm wgt., and a 22 kg difference in LWL. Similar trends are recorded in Trial 2, in cattle numbered 10, 8 and 19, and in Trial 3 with cattle numbered 526, 541, 511 and 533.

When examining the significance of the affect of LWL on the Dr%, Table 20 shows that in Trial 1 there were indications that as LWL increased so the Dr% decreased. The plot of the raw data from Table 20 is shown in Figure 3. The very low r^2 value ($r^2 = 0.10$) and the random distribution of the data indicates that the derived line was a poor fit to the data.

Table 21 shows that in Trial 2 there is a strong relationship, recording that as the LWL increased the Dr% ($P<0.001$), the relationship is a negative one. This is signified by the line plotted in Figure 4 using the equation ($-0.065(LWL_{ij}) + e_{ij}$). The r^2 value for this data is higher ($r^2 = 0.52$) than in Trial 1, although again the model did not explain all the variance in the data.

Table 22 records that the relationship between the LWL and the Dr% is not significant, (Figure 5). Combining the results of all three trials, Table 23, recorded that overall there is a significant relationship between Dr% and LWL ($p<0.001$). Figure 6 demonstrated that as LWL increased the Dr% decreased, but the r^2 value shows that the data is widely spread ($r^2 = 0.19$). In considering the negative trend shown in Table 22 and Figure 6, it must be noted that the significance of this table is biased by the reducing mean Dr% that occurred from Trial 1 to 3 (55.5% - 49.5%) (Table 18). It is more significant to recognise that the slope of the line ($ßx_{ij}$) in Figures 3 to 6 predicts the correct negative effect that LWL had on the Dr%, the equation given in Table 23 over states this effect to such an extent that no line has been plotted.

The LWL in each trial [divided by group] was analysed to discover whether it was affected by temperature, duration, stocking density, and/or fluid consumption. The results of these tests proved inconclusive, predominantly due to the small sample size ($n=6$). Overall the results indicate that there was a relationship between the size of the LWL and the Dr%, but it is unclear as to why there should have been the very large differences in the LWL within each trial.

Table 20: The Significance of the Effect that Live-Weight Lost Between the Farm and Slaughter had on the Dressing-out Percentage of Cattle in Trial 1.

Dependent Variable : Dressing-out percentage (Dr%).

Independent Variable : Live Weight Loss between Farm and Slaughter (kg) (LWL).

Independent variable	Equation $Y_{ij} = \mu_i + \beta x_{ij} + e_{ij}$ [a]	p	r^2
LWL	$Y = 56.18 - 0.065(LWL_{ij}) + e$	0.095	0.10

a: $Y_{ij}=\mu i+\beta x_{ij}+e_{ij}$

Y_{ij} = *the observation on individual j from group i.*

μi = *the mean of the population that corresponds to the* i^{th} *group.*

βx_{ij} = *the slope of the regression line, specifies the change in Y per unit increase in x.*

e_{ij} = *a random residual error unique to the individual observation, assumed to be normally distributed with mean zero and variance* σ.

b: *Analysis of Variance working ; Appendix Table 5.1*

Figure 3 : Trial 1, Raw Data Showing the Relationship Between Dr% and LWL.

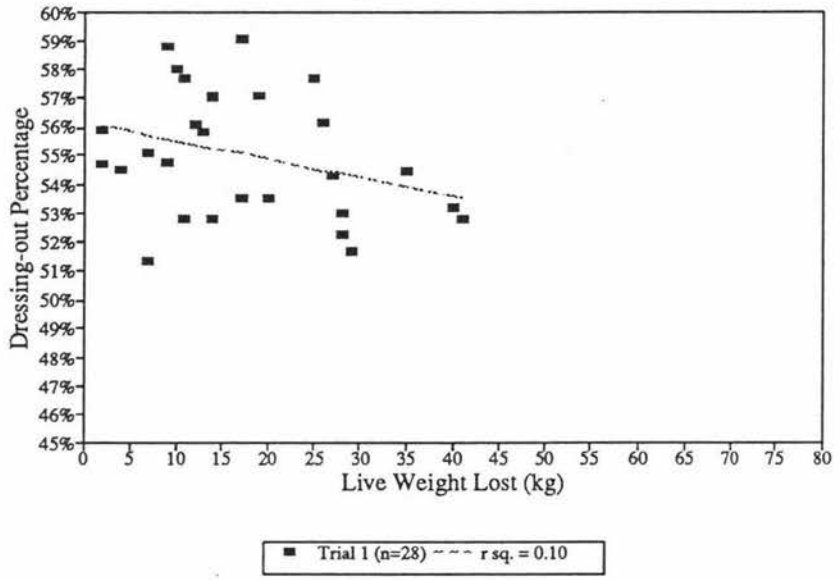


Table 21 : The Significance of the Effect that Weight Loss between Farm and Slaughter had Upon the Dressing-out Percentage of Cattle in Trial 2.

Dependent Variable : Dressing-out percentage (Dr%).

Independent Variable : Live Weight Loss between Farm and Slaughter (kg) (LWL).

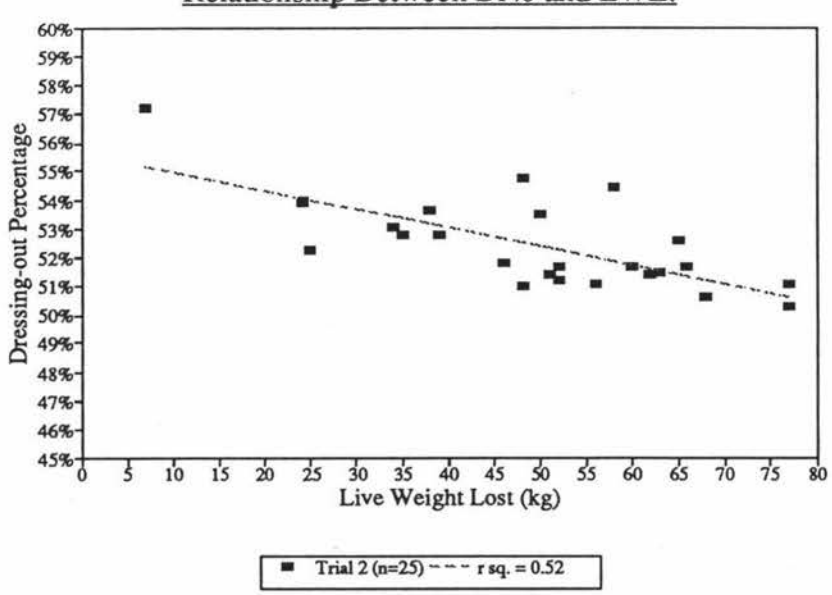
Independent variable	Equation $Y_{ij} = \mu_{ij} + \beta x_{ij} + e_{ij}$ [a]	p	r^2
LWL	$Y_{ij} = 55.64 - 0.065(LWL_{ij}) + e_{ij}$	0.0001	0.52

a: $Y_{ij}=\mu i+\beta x_{ij}+e_{ij}$

Y_{ij} = *the observation on individual j from group i.*
μi = *the mean of the population that corresponds to the* i^{th} *group.*
βx_{ij} = *the slope of the regression line, specifies the change in Y per unit increase in x.*
e_{ij} = *a random residual error unique to the individual observation, assumed to be normally distributed with mean zero and variance* σ.

b: *Analysis of Variance working ; Appendix Table 5.2*

Figure 4: Trial 2, Raw Data Showing the Relationship Between Dr% and LWL.



'able 22 : The Significance of the Effect that Live-Weight Loss between Farm and Slaughter had Upon the Dressing-out Percentage of Cattle in Trial 3.

)ependent Variable : Dressing-out Percentage (Dr%).

ndependent Variable : Live Weight Loss between Farm and Slaughter (kg) (LWL).

Independent variable	Equation $Y_{ij} = \mu_{ij} + \beta x_{ij} + e_{ij}$ [a]	p	r^2
LWL	$Y_{ij} = 52.73 - 0.030(LWL_{ij}) + e_{ij}$	0.28	0.04

a: $Y_{ij}=\mu i+\beta x_{ij}+e_{ij}$

Y_{ij} = *the observation on individual j from group i.*
μi = *the mean of the population that corresponds to the* i^{th} *group.*
βx_{ij} = *the slope of the regression line, specifies the change in Y per unit increase in x.*
e_{ij} = *a random residual error unique to the individual observation, assumed to be normally distributed with mean zero and variance* σ.

b: *Analysis of Variance working ; Appendix Table 5.2*

Figure 5: Trial 3, Raw Data Showing the Relationship Between Dr% and LWL.

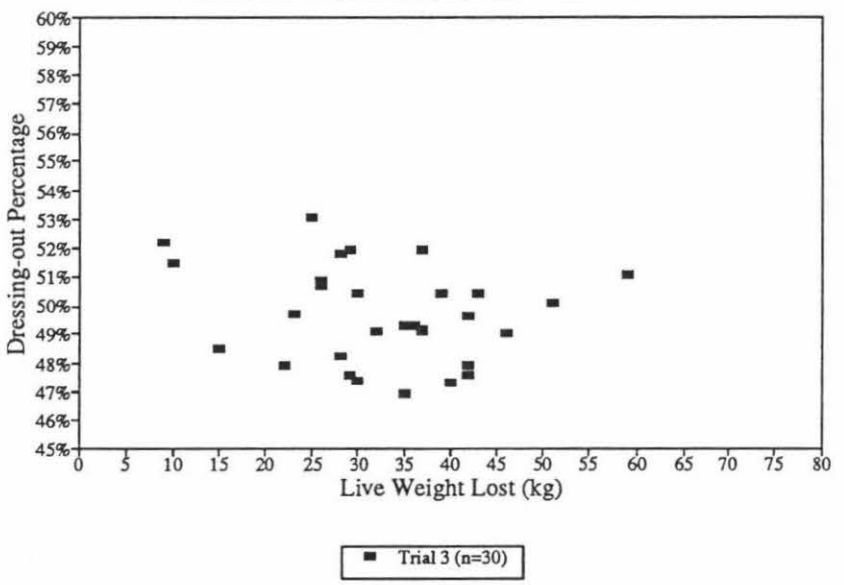


Table 23 : The Significance of the Effect that Live-Weight Loss between Farm and Slaughter had Upon the Dressing-out Percentage of Cattle, all Trials Combined.

Dependent Variable : Dressing-out Percentage (Dr%).

Independent Variable : Live Weight Loss between Farm and Slaughter (kg) (LWL).

Independent variable	Equation $Y_{ij} = \mu_{ij} + \beta x_{ij} + e_{ij}$ [a]	p	r^2
LWL	$Y_{ij} = 176.8 - 275.7(LWL_{ij}) + e_{ij}$	0.0001	0.19

a: $Y_{ij}=\mu i+\beta x_{ij}+e_{ij}$

Y_{ij} = *the observation on individual j from group i.*

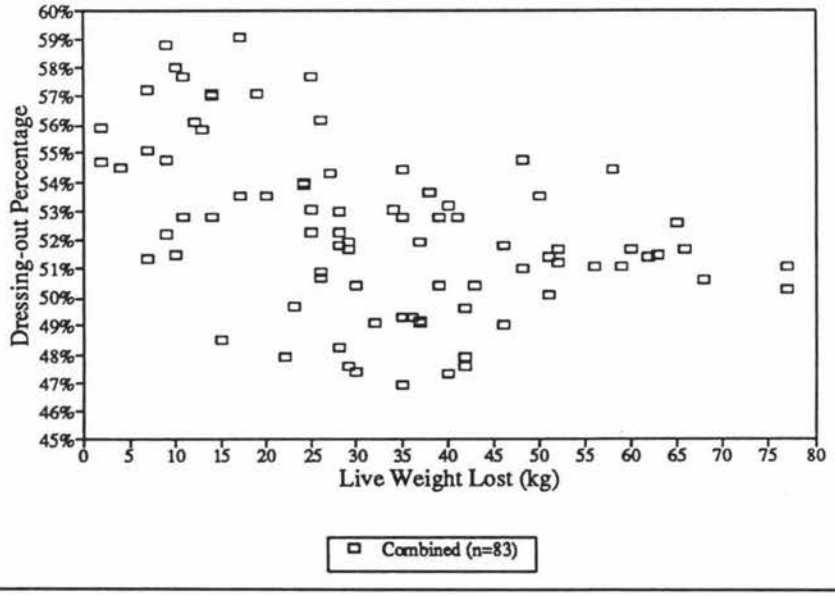
μi = *the mean of the population that corresponds to the* i^{th} *group.*

βx_{ij} = *the slope of the regression line, specifies the change in Y per unit increase in x.*

e_{ij} = *a random residual error unique to the individual observation, assumed to be normally distributed with mean zero and variance* σ.

b: *Analysis of Variance working ; Appendix Table 5.2*

Figure 6: Combined Raw Data Showing the Relationship Between Dr% and LWL.



4.3 EXPERIMENT TWO

4.3.1 Introduction

The aim of experiment two was to test the null hypothesis (Refer 3.1 Aims and Objectives) to the 95% significance level, in order to ascertain whether there are any economic benefits to be gained through the supply of an electrolyte fluid. A total of 113 cattle were used in four separate trials.

The data collected from the 30 animals in Trial 4 was not used, as the cattle in this trial did not drink any of the electrolyte solution supplied to them during the 19.5 hours they were in lairage. In Trial 2, 1 animal from the control, and 5 from the test group, were dropped out of the results because these animals required further trimming on the Detain-rail (D-Rail), over and above the defined standard carcass trim (Refer Appendix 2). The extra trimming could not be weighed, therefore a true dressing-out percentage could not be determined for these cattle. Consequently, a total of 77 cattle were used in these results, divided between the water ($n=40$), and the electrolyte ($n=37$), groups.

4.3.2 Results of Cattle Supplied an Electrolyte Solution Compared to Those Supplied Water

The raw data for the following results can be found in Appendix 1. Table 24 gives individual trial statistical data, and Table 25 gives the amalgamated statistical data, related to live and carcass weights, and the dressing-out percentages. In attempting to establish whether there were any improvements in the dressing-out percentage through the supply of the electrolyte solution, it was important (due to the variability in the recording process) to ensure that in the development of the data there was no significant difference between the two groups (Water and Electrolytes) (Table 25).

Table 24 : Mean Totals of All Raw Data Collected from Cattle Supplied Either Electrolytes or Water While in Lairage.

Cattle Supplied Water (W)

Cattle Supplied Electrolytes (E)

	Trial 1		Trial 2		Trial 3	
Mean Totals	$W_{(n=14)}$	$E_{(n=14)}$	$W_{(n=12)}$	$E_{(n=13)}$	$W_{(n=15)}$	$E_{(n=15)}$
Farm wgt. (kg)	550.6±21.7	547.3±35.9	$652.0_{[647.6]}$±27.3	$664.8_{[663.5]}$±19.7	459.9±28.8	476.7±27.5
Plant wgt. (kg)	527.0±20.9	535.7±36.0	$604.6_{[599.5]}$±28.6	$614.3_{[618.3]}$±21.3	428.6±28.4	442.5±25.3
Carcass wgt. (kg)	305.6±13.2	298.7±26.5	$342.4_{[339.9]}$±17.1	$348.2_{[351.4]}$±13.2	229.1±17.4	236.1±14.1
LWL (kg)	23.6±9.6	11.5±7.9	47.4±14.6	50.4±19.1	31.3±9.2	34.2±12.3
LWL as % of Fm. wgt.	4.3±0.02	1.8±0.01	7.3±0.02	7.6±0.03	6.8±0.02	7.2±0.02
Cass. wgt as % of Pl. wgt.	58.0±0.02	55.8±0.02	$56.6_{[56.7\%]}$±0.02	$56.7_{[56.8\%]}$±0.01	53.5±0.02	53.3±0.01
Cass. wgt. as % of Fm. wgt.	55.5±0.02	54.6±0.02	$52.5_{[52.4\%]}$±0.01	$52.4_{[52.9\%]}$±0.02	49.5±0.02	49.5±0.02
Carcass on D-Tain rail.	0	0	1	5	0	0

[] Data in brackets is the adjusted means, with carcasses that went down the D-Tain rail removed.

Table 25 : The Combined Average Live and Carcass Weights, and Dressing-out Percentages, for Cattle Supplied Water or an Electrolyte Solution.

Variable label		Electrolyte Group (n=37)	Water Group (n=40)	p
Live weight at the farm gate (FW)	(kg)	543.8 ± 77.3	543.3 ± 80.1	0.53
Live weight in the pre stun (PW)	(kg)	515.8 ± 74.8	510.0 ± 74.4	0.44
Transport and lairage weight loss (FW - PW)	(kg)	28.0 ± 19.0	33.3 ± 15.1	0.67
Hot carcass weight (CW)	(kg)	284.8 ± 49.4	286.3 ± 49.5	0.76
PW/FW * 100	(%)	94.8 ± 3.3	93.9 ± 2.4	0.45

Where p = the significance of the difference between the two means.

Table 25 demonstrates that :

(1) There was no significant difference between the mean group live weights at the farm gate [between the two groups].

(2) There was no statistical difference in the pre-stun weights between the two groups.

(3) There was no statistical difference in the live-weight lost between the two groups.

(4) There was no statistical difference in the hot carcass weights between the two groups.

Table 26 : Comparing the Significance of the Difference Between the Dressing-out Percent of Cattle Supplied Either Water or an Electrolyte Solution, Using Analysis of variance and Co-variate Analysis.

Trial :	Analysis of Variance	n	Dr%(LSM)[1] ± Std Error	p
All Trials Combined	(Dr%, Water)	40	52.54 ± 0.454	0.48
	(Dr%, Elect)	37	52.18 ± 0.449	
Trial 1	(Dr%, Water)	14	55.53 ± 0.583	0.25
	(Dr%, Elect)	14	54.55 ± 0.583	
Trial 2	(Dr%, Water)	12	52.49 ± 0.519	0.56
	(Dr%, Elect)	13	52.97 ± 0.609	
Trial 3	(Dr%, Water)	15	49.78 ± 0.437	0.68
	(Dr%, Elect)	15	49.54 ± 0.437	
Trial :	Co-variate Analysis			
All Trials Combined	(Dr%, Water)	40	52.6 ± 0.43	0.32
	(Dr%, Elect)	37	52.0 ± 0.42	
Trial 1	(Dr%, Water)	14	55.59 ± 0.56	0.22
	(Dr%, Elect)	14	54.59 ± 0.55	
Trial 2	(Dr%, Water)	12	52.53 ± 0.49	0.48
	(Dr%, Elect)	13	52.51 ± 0.48	
Trial 3	(Dr%, Water)	15	49.9 ± 0.47	0.49
	(Dr%, Elect)	15	49.6 ± 0.47	

LSM : Least Square Mean
Dressing-out Percentage, Water Group (Dr%,Water)
Dressing-out Percentage, Electrolyte Group (Dr%,Elect)

The results from the first half of table 26 show that in no trial nor in the combined mean results was there a significant difference in the mean dressing-out percentages to signify that there were any benefits behind supplying an electrolyte solution to cattle while in lairage. In Trial 1 the difference in the Dr% was 0.98% in favour of the cattle supplied water. In Trial 2 the difference was 0.48% in favour of the cattle supplied electrolytes, and in Trial 3 the difference was 0.24% in favour of cattle supplied water.

There was a substantial difference in the mean on farm live weights of the three trials (Table 24). The range in the mean on farm live weights was, 664.8 vs 459.9 (n=77), a range of 204.9 kg. This variation in the range was caused by the difficulty in getting an adequate supply of cattle for this research study, and while more standardised live

veights would have been preferable this study was forced to accept stock as they ecame available. This problem caused a ripple down effect where-by between trials here was a discernable difference in the means (Table 24).

Co-variate analysis was used to remove the effects that the on-farm live-weights may iave had on the analysis. The result of this can be seen in the second half of Table 26, vhile the co-variate analysis caused a small change in the mean dressing-out ercentages, the change was not great enough to alter the significance of the results. In he second half of Table 26 the combined mean dressing-out percent was greater for the vater groups than the electrolyte groups (52.6% vs 52.0), but this difference is not statistically significant. The complete statistical tables relating to the analysis of variance can be found in Appendix 6.

In Table 26 the average yield from the first three trials is combined, even though there was a change in the concentration of the solutions between the first and the second trials, from 20ml/litre of Multigro concentrate down to 10ml/litre. If the average yields are calculated for the different concentrations of Multigro used the results would have been:

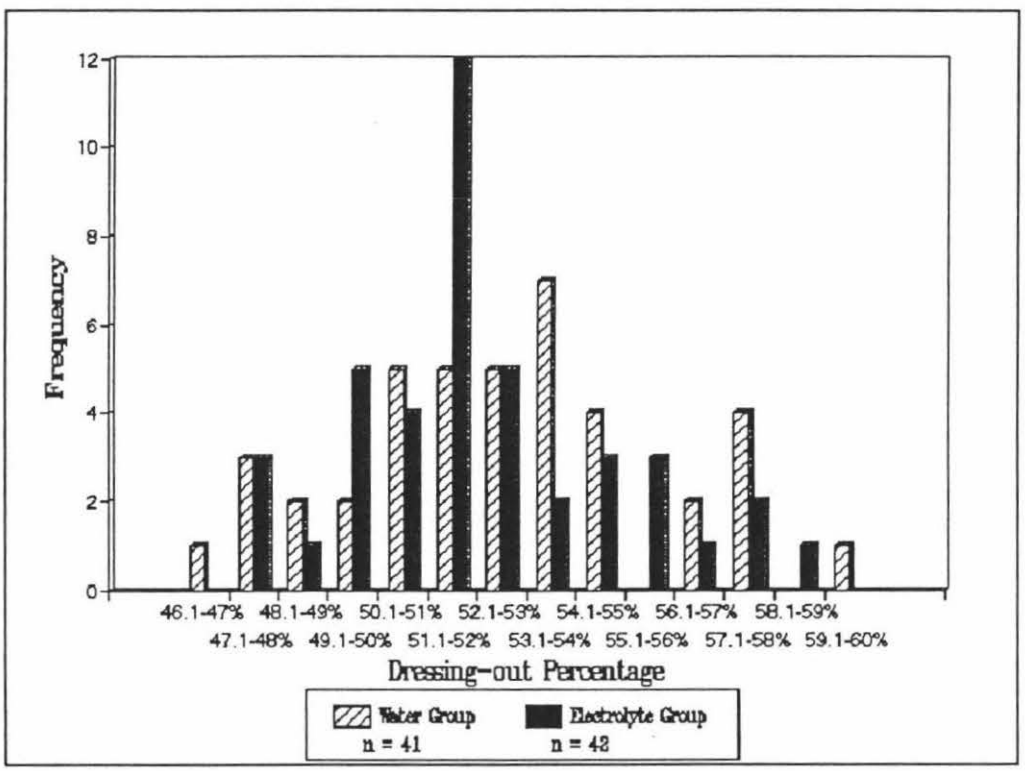
Table 27 : Depicts the Dressing-out Percentages for the Different Multigro Concentrations Supplied to Cattle While in Lairage.

		Electrolyte Group (%)	Water Group (%)
Dressing-out Percentage, Trial 1.	(20ml/l)	54.6	55.5
Dressing-out Percentage, Trial 2 and 3.	(10ml/l)	51.3	51.1

The difference in the relative yields from Table 27 was still not significant, although the result via the supply of an electrolyte solution containing 10ml/l Multigro did reverse the trend seen in Table 26, resulting in electrolytes being slightly more beneficial than water, 51.3% vs 51.5% (E>W). However the differences are within the experimental error of the trial and therefore not significant. In the following Figure 7, the distribution

of the individual mean dressing-out percentages were examined using a frequency graph. The distribution of the data between groups is also not significantly different.

Figure 7 : Frequency Table Depicting the Distribution of the Two Groups of Cattle Supplied Either Water or an Electrolyte Solution While in Lairage.



The above figure shows that both groups of cattle had normal distribution curves, this indicates that there was not a significant difference between the distribution of the two groups.

4.4 PALATABILITY TRIAL

4.4.1 Introduction

The aim of the palatability trial was firstly to discover if cattle initially resist drinking the electrolyte solution, and secondly if cattle, when given a choice between the electrolyte solution and water, will drink the electrolytes in preference to water. The palatability trial was conducted in August, after Experiment Two had been completed. The objective was to try to find out why the results in Experiment Two were largely insignificant.

4.4.2 Results of the Palatability Trial

The palatability trial, Table 28, showed that cattle had a strong preference for water, ahead of electrolytes in the first 24 hours. Figure 8, portrays the obvious difference in the level of consumption between the electrolyte solution and water in the first 24 hours.

The results of the palatability trial showed that in the first 24 hours of access, the cattle in Group 1 (offered only water) drank 26 litres ($n=2$), the cattle in Group 2 offered a choice of water or an electrolyte solution, drank 18 litres of water and 2 litres of electrolytes ($n=4$), and the cattle in Group 3 offered only an electrolyte solution drank only 2 litres ($n=2$). On average, Group 1 cattle drank 13 litres per head, Group 2 cattle drank 5 litres per head, and Group 3 drank 1 litre per head.

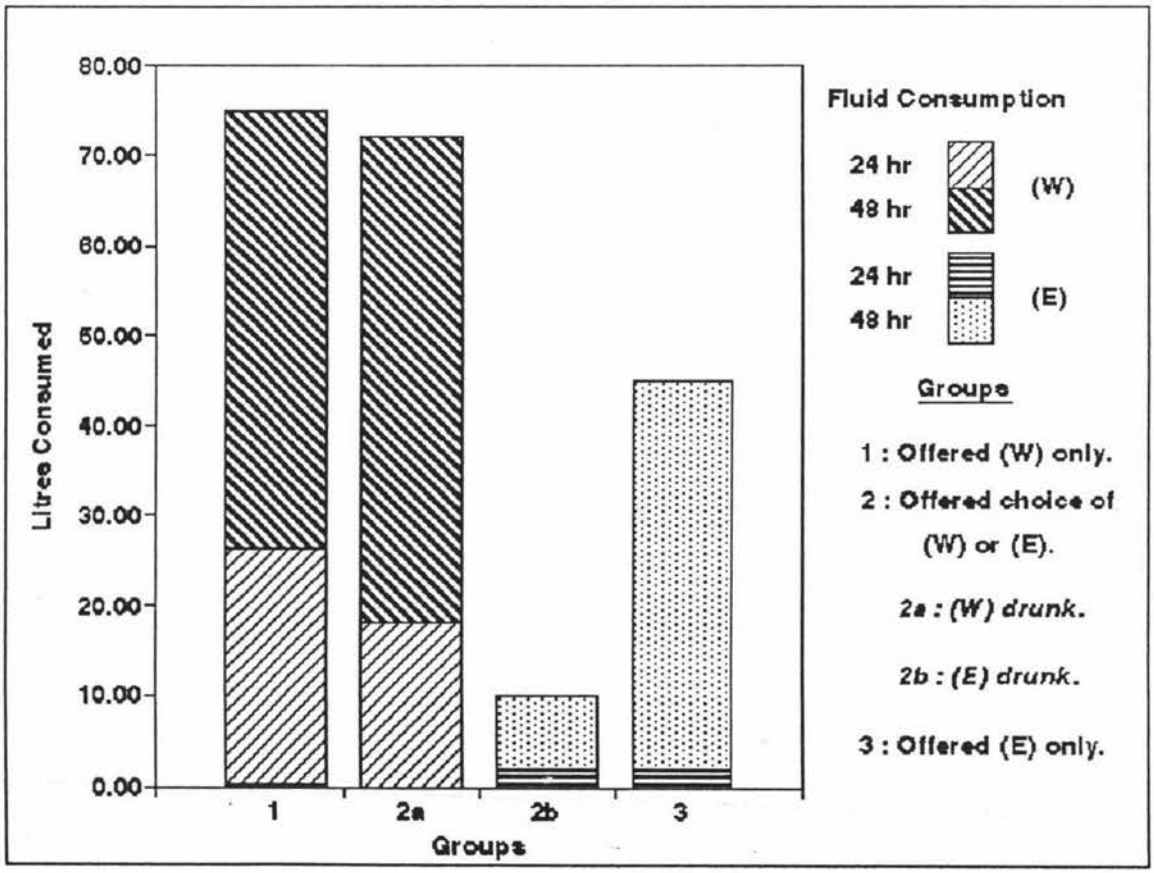
In the second 24 hours, Group 1 drank 49 litres, averaging 24.5 litre per head, Group 2 drank 54 litres of water and 8 litres of electrolyte solution, averaging 13 litres of fluid consumption per head, and Group 3 drank 43 litres, averaging 21.5 litres of electrolyte fluid per head.

In group 2, where the cattle were offered a choice between water or the electrolyte solution they still drank 10 litres of the solution, the majority of this was on the second day.

Table 28 : The Results of the Palatability Trial : Comparing the Consumption of Water Against Multigro by Cattle, Over 48 Hours.

Groups	1 **Water** only. *n=2*	2a **Water** preferred to Electrolytes.	2b **Electrolytes** preferred to Water. *n=4*	3 **Electrolytes** only. *n=2*
Fluid Consumption After 24 Hours (L)	26	18	2	2
Fluid Consumption After 48 Hours (L)	49	54	8	43
Total Consumption (L)	**75**	**72**	**10**	**45**

Figure 8 : Palatability Trial : Establishing the Preference of Cattle when Offered a Choice of Water or an Electrolyte Solution to Drink.



CHAPTER FIVE

DISCUSSION

5.1 THE SUPPLY OF AN ELECTROLYTE SOLUTION

5.1.1 Introduction

On the basis of the results recorded in Experiment Two this research study accepts the null hypothesis (as stated in 5.2.1) and concludes that there was no significant advantage in supplying Multigro (at $10ml^{-1}$ l) to cattle prior to slaughter, under commercial conditions. The economic benefits of providing an electrolyte solution to cattle prior to slaughter were not significant. Consequently no justification could be found to warrant the introduction of this electrolyte solution into the lairage area on a permanent basis.

This result is different to that achieved by Schaefer *et al.* (1990) and Gortel *et al.* (1992) who recorded improvements in the dressing-out percentage of cattle (supplied an electrolyte solution) in the order of 0.9 to 3 percent. Both proved that there were significant advantages to be achieved through the supply of an electrolyte solution to cattle prior to slaughter, though neither had tested their conclusions under commercial conditions. Wood (1994, private communication) supplied an electrolyte solution to cattle [in a commercial situation] and estimated that the dressing-out percentage improved by up to 1 percent 50 percent of the time.

The question to be asked is, "why then did this trial not achieve the same results as Schaefer *et al.* (1990), Gortel *et al.* (1992), or Wood (1994) ?"

In conducting this study three other sets of results were analyzed which require discussion before the above question can be addressed.

5.1.2 Multigro

The electrolyte/glucose concentrate used in this trial was supplied by Coast Biologicals Limited, and licensed under the Animal Remedies Act 1967 as Multigro, licence No. 6345. The origin of its use in this study comes from Coast Biologicals Ltd. interest in following up the research of Schaefer *et al.,* 1990, 1992, and Gortel *et al.,* 1992.

Multigro is currently marketed by Coast Biologicals as a dietary supplement for sheep, dairy and beef cattle, horses, goats, deer and pigs. It contains 16 minerals and 18 amino acids and contains the preservative p-hydroxybenzoic acid (sodium salt). Multigro is a by-product created via the extraction of agar from seaweed, to this is added feed grade molasses which is the source of sucrose in Multigro.

The recommended applications for Multigro include drenching, addition to dry feeds, spread upon hay or silage, or added to water troughs. One of the advantages of Multigro is that its use with cattle incurs no withholding period prior to slaughter.

Multigro was originally used in this trial at a dilution rate of 20ml/litre, in the second and third trials this rate was dropped to 10ml/litre. The change in rates was a consequence of the differing formulations recorded in Table 14. The original rate (20ml/L) was decided upon because it compares closely with the electrolyte formula used by Gortel *et al.* (1992). It was later decided to use the elemental analysis supplied by AgResearch as the correct formula for Multigro, the result of which saw the introduction of Multigro diluted to 10 ml/L.

The major difference in the second formulation (10ml/L) to Gortel's solution was the glucose concentration (Table 30). The glucose level in Multigro was not adjusted as Schaefer *et al.* (1990) recorded dressing-out percentage improvements using an electrolyte solution with a nil glucose content.

The dilution of Multigro concentrate 100 times results in the preservative, p-hydroxybenzoic acid (sodium salt), no longer being effective in preventing the

development of bacterial growth. This resulted in the development of bacterial populations in the over-head tank containing the solution, the source of the bacteria was assumed to be air borne microbes found in dusty areas, typical of a lairage situation. Rohde, (1968) states that Nutrient Agar (1.5%) has a NaCl concentration of 8g/litre, and is designed to encourage the growth of bacterial organisms, below this sea water has a NaCl concentration of 2.7g/litre (Gerhardt 1981) and the Multigro diluted solution has a NaCl concentration of 1.08g/litre, these concentrations of NaCl are to low to inhibit the growth of bacterial cultures, and hence over time the resulting micro-organisms were able to develop in the electrolyte solution.

During the summer months when fluid consumption was high (Table 15) the microbes would present no problem, but in the cooler months microbes would be problem if fluid consumption dropped to a level which would allow the build up of bacteria in the troughs. To protect against this, either more vigorous cleaning of the toughs would be required or an increase in the concentration of the preservative would be needed, which would require the rerun of the palatability trial to assess the impact of the change in formulation.

5.1.3 Experiment 1

5.1.3.1 The Effect of Duration, Temperature and Stocking Density on the Water Consumption of Cattle in Lairage

The provision of water in lairage meets two requirements, it satisfies animal welfare needs and offers the opportunity to minimise potential dressing-out yield losses caused by dehydration. The supply of water has been proven to be beneficial in increasing the dressing-out percentage (Dr%) of cattle compared to not supplying any water (Wythes 1984, Wythes *et al.* 1980, Jones *et al.* 1992). Denton (1982) suggested that animals drink when plasma osmolality decreases by 2-5 osmol/kg, or when cellular water decreases by 1-3%. At this point an animal will drink only enough to replace the water

deficit, the failure of the animal to drink at this point may lead to the animal becoming dehydrated.

The consumption of fluids by cattle in lairage was of paramount importance to the significance of this trial. The failure of cattle to drink while in lairage would have made this study irrelevant. Experiment 1 aimed to prove that cattle do require water while in lairage, and to provide an estimate of how much fluid was needed. Over 9 trials the cattle were observed to drink on average 13.1 L/hd prior to slaughter (Table 16). Water consumption by cattle in lairage was seen to be influenced by the duration and temperature in lairage, but did not seem to be affected by the stocking density (Table 17).

The water consumption of cattle in lairage tended to increase with an increasing mean daily temperature. Over the first six trials conducted during January to March the average water consumption was 18.0 L/hd (mean temp. 16.0°C), during April and May mean water consumption decreased to 3.4 L/hd (mean temp. 12.2°C). This indicates that water consumption decreased by 82% between March and early May in response to a drop in the mean daily temperature to 12.2°C.

Water consumption also increased as duration in lairage increased ($p<0.05$). The duration in lairage was seen to have a more significant effect upon water consumption than temperature. In two cases water consumption was recorded to be greater for cattle held at lower temperatures for a longer duration period (Section 4.2.2). The combined effect of duration and temperature significantly influenced water consumption ($p<0.025$). The significance of this result is that cattle must be ensured adequate access to water during the hotter time of the year, especially if the time in lairage is extended.

The different stocking densities, that the groups of cattle experienced in lairage, had no significant effect upon their water consumption. In considering the effect of the stocking density on water consumption, it should be noted that this research was not designed to examine this variable, or the above variables properly. The consequence of this is was that more questions were raised than answered.

The questions this experiment raised are :

1. Why is the mean water consumption (13.1 L/hd, mean temp. 20.75°C) so far below the mean water demand suggested by the NRBC (Table 3). The NRBC state that when the mean daily temperature is between 14.4 and 21.1°C a 454 kg cattle beast will demand 40.9-47.7 L/hd/day (figures include dry matter intake)?

2. Secondly, it is unlikely that each animal consumed the same amount of water, therefore how much water did each animal consume ?

These questions are important because it has been proven that cattle without access to water have a lower Dr% (Jones *et al.* 1992). Yet in this experiment water consumption did not significantly affect the live weight lost (LWL) or Dr%. If individual water consumption could be measured against the LWL and Dr% then the result may be more significant. Jones *et al.* (1992) recorded that the deprivation of water reduced the dressing-out percentage of cattle by 0.9% over 12 hours, increasing to 1.1% after 18 hours. Contrary to the result presented by Jones, it was not proven that the supply of fluids to cattle in lairage significantly effects the animals LWL or Dr%.

5.1.3.2 The Effect of Live Weight Loss on the Dressing-out Percentage of Cattle

An examination of Table 24 showed that for both the Water and Electrolyte groups there was a substantial difference in the dressing-out percentages within the separate groups. In Trial 1 the range in the dressing-out percentages for the Water (W) and Electrolyte (E) groups were (W) 6.3% and (E) 7.5%, in Trial 2 it was (W) 4.5% and (E) 6.6%, and in Trial 3 (W) 6.2% and (E) 4.5%. The higher dressing-out percentages (Dr%) tended to be associated with a lower live weight loss (LWL) (Table 19).

The mean loss in the live weight of all the cattle trialed (trials 1 to 3), between the farm and slaughter, was 32.2 kg per head (Water group = 33.3 kg, Electrolyte group = 28.0

kg), with a range of 2 to 77 kg. The combined results showed that as the LWL of an animal increased, its Dr% decreased ($p<0.01$) (Table 23). The individual trials showed a less significant result. Trial 1 supports a trend that indicates an increasing LWL results in a decreasing Dr% (Table 20), Trial 2 indicated that there was a definite relationship ($p<0.001$) (Table 21), whilst Trial 3 indicated that there was no relationship between LWL and the Dr% (Table 22).

The reason for the variability between the results in the three trials can be seen in Figures 3 to 5. The quality of the data is poor, in that the variation in the individual data points makes it difficult to plot a straight line. This in turn makes it difficult to identify any clear trends. In Figure 6 a more definite trend can be identified, but in identifying this trend it must be noted that this effect is being overstated by the differences in the mean dressing out percentages between each trial. Which when plotted in sequence are 55.5, 54.6, 52.5, 52.4, 49.8, 49.5 (%) (Table 18).

Unfortunately the data collected in this second part of Experiment 1 does not explain why the cattle lost so much live weight, or how the LWL effected the Dr%. The LWL was not seen to be significantly effected by stocking density, temperature, or duration in lairage. It is important to note that a relationship between one or a combination of these three variables and the LWL is not disregarded, as the sample size ($n=6$) used was too small to establish a definitive result. This was probably due to an experimental methodology that was not designed to measure these interactions.

The study showed that the LWL was not affected to any great extent by fluid consumption whilst the cattle were in lairage [the significance of this result is affected by the small sample size]. The data collected from the fourth trial, group 7 in Table 15, also supports this result. In the trial the cattle with access to water consumed on average 1.4 L/hd over 19.5 hours, yet their LWL ranged from 6 - 57 kg. The cattle with access to the electrolyte solution showed a similar trend with the group consuming nil (0.0 L/hd) solution in 19.5 hours and their LWL ranged from 0 - 42 kg. Similar internal group variations were observed within Trials 1 to 3, for example cattle in Trial 1 recorded a mean water consumption of 29.9 L/hd with a range in LWL of 10 - 41 kg.

The provisional conclusion from this study would appear to be that fluid consumption in lairage had no direct bearing on the LWL of cattle. However before such a conclusion is accepted a more rigorous study should be conducted to evaluate the influence of fluid consumption on the LWL of cattle. Future studies need to take into account individual fluid consumption and an attempt should be made to gauge the state of the gut-fill of the individual cattle, via either obtaining data about the history of the animals from the producer (farmer), or measuring their food intake prior to on-farm weighing.

In this study the dressing-out percentage (Dr%) of an animal was influenced by both the on-farm live weight (FmW) and the hot carcass weight. It is accepted that with access to water, the carcass weight (kg) of a ruminant will not change dramatically within the first 24 hours of being deprived of feed (Wythes 1984). Therefore it is suggested that the LWL is a factor of pre-slaughter weight loss, which is dominated by the state of the gut-fill of an animal. Shorthose and Wythes, (1988) state that the gastrointestinal tract, when dry matter is included, can account for up to 22% of the live weight of an animal.

Cattle are held in lairage in order to discharge their gut-fill, thereby lowering the risk of contamination of the carcass during evisceration. The more weight an animal is carrying at the time of the on-farm weigh-in [with direct reference to its gut-fill] the greater will be its assumed loss over its time in lairage (mean duration 21.27 hrs, Table 16) it is held in lairage, resulting in a lower Dr%. The reverse is also assumed, whereby an empty animal will weigh less and lose less live weight while in lairage, thereby recording a higher Dr%. This theory behind the loss in live weight assumes that the cattle entering the lairage area are not afflicted with a malady (e.g. diarrhoea or vomiting) that may cause a disproportionate loss in live weight compared to the state of its gut-fill.

Table 19 records several examples of cattle with similar carcass weights, but substantially different farm weights, with the heavier animal recording a larger LWL, resulting in them having a lower Dr%. This result is suggested to be due to a variation between the cattle with regards to the state of their gut-fill.

The result of this second half of Experiment 1 is that again more questions are posed than are answered. A larger LWL tends to result in a decreased Dr%, but this does not necessarily mean that the lower Dr% is the result of the LWL reducing the carcass weight, the carcass weight of an animal may not be affected at all.

Secondly, fluid consumption was not recorded as effecting the LWL, yet several researchers suggest that water consumption does effect the dressing-out percentage of cattle (Wythes, 1984; Wythes *et al.* 1980, 1982, 1985; Jones *et al.* 1990), if this is correct then water consumption may also effect the LWL.

In considering the total impact of Experiment 1, it was observed that the LWL and water consumption varied substantially (mean LWL 28.0±19.0 (W), 33.3±15.1 (E), and mean water consumption 13.14±8.4 L/hd) The question that is raised is "were these variations related to each other in any way, and if so were there any other variables that affected the LWL and water consumption, apart from mean daily temperature and time in lairage ?

Suggested answers to consider are that variation in the gut-fill of the cattle affected the subsequent demand for fluids. The supply of feed, particularly dry feeds, to cattle is known to increase the demand of an animal for water. Alternatively the demand for water between cattle is relatively static, yet for some reason not all cattle gained adequate access to the lairage trough, which in turn had an impact on the LWL and Dr% of the cattle.

Ideally a study into the impact of the effects of LWL and water consumption upon carcass weight loss and the dressing-out percentage needs to be considered. The cattle should be monitored prior to entering the lairage area, and a record of individual feed and water consumption be kept until slaughter.

In relation to the result of Experiment 1 the most important point to note is that offering cattle the choice of water or the electrolyte solution did not significantly effect the live weight lost. This result was different to that recorded by Gortel *et al.* (1992), who

measured that cattle supplied water lost less weight than those supplied the electrolyte solution, and suggested that this was due to the difference in the mean amount of fluids consumed. The cattle consumed 12.7 L/hd more water than electrolytes (Table 29).

5.1.4 Palatability and its Effect Upon Electrolyte Fluid Consumption

The results from section 4.4 suggest that the electrolyte solution (Multigro) used as a source of fluid was acceptable to the cattle, but could not be considered palatable as this implies a preference for the solution over plain water. The cattle initially resisted drinking the electrolyte solution, but eventually consumed it in quantity if offered no other choice.

In the first 24 hours of introduction to the electrolyte solution the cattle in group 3 drank up to 13 litres less fluid than the cattle in group 1 which were supplied water. It is difficult to explain why the cattle in group 2 drank so much less water than those in group 1, the cattle were all from the same herd and had been brought in off the farm on the same day. A factor in this difference may have been the small sample size used ($n=8$) exaggerating the affect of a number of uncontrolled variables. If for example one of the cattle in group 2 had consumed a quantity of water immediately prior to penning, resulting in it not drinking in the first 24 hours, the effect of this would have been over-stated in the small sample of cattle used.

In the second 24 hours the cattle supplied the electrolyte solution consumed 21.5 litres each compared to 24.5 litres per head of water consumed by group 1. This may indicate acceptance of the taste of the electrolyte solution or be a factor of 'increased demand' for fluids, group 3 having consumed only 2 litres over the first 24 hours. It should be noted that in group 2, consumption of the electrolyte solution went up four-fold (mean = 2 L/hd, $n=4$), which may indicate that while there is no preference for the electrolyte solution the cattle will drink it.

If cattle do not initially drink the electrolyte solution because the taste is unfamiliar to them, then further work is required to develop a readily acceptable electrolyte solution, particularly as cattle in lairage do not usually have 24 hours to accept a new drink. The average time in lairage in this study was 21.3 hours.

The results from this trial showed that in the first 24 hours there was a strong resistance to drink the electrolyte solution, whereas in the second 24 hours the cattle drank more willingly. During Experiment 2 there was not such an obvious preference for water over electrolytes, and while the cattle drank on average less of the electrolyte solution than water (4.6 litres less over the 4 trials), the difference recorded in the mean consumption levels was less than that recorded by Schaefer *et al.* (1990) or Gortel *et al.* (1992). Refer to Table 29.

Table 29 : The Difference in the Amount of Electrolyte Solution Consumed Compared to Water.

Level of Fluid Consumption (Litres)	Water (L)	Electrolyte (L)	Difference (L)
Schaefer *et al.* (1990)	17.4	12.0	5.4
Gortel *et al.* (1992)	29.7	17.0	12.7
Experiment Two (Multigro)	17.9	13.3	4.6

5.1.5 The Theory as to Why Cattle Supplied an Electrolyte Solution did not Improve Their Carcass Weight

At no time, in any of the trials, was there a significant result to suggest that the supply of an electrolyte solution to cattle in lairage would improve their dressing-out percentage (Table 26). The results from Experiment 2 indicated that (Trial 1) the cattle supplied electrolytes at 20 ml l^{-1} recorded an average dressing-out percentage 0.9% less than the cattle given water. In trials 2 and 3 the cattle were provided an electrolyte solution at 10 ml l^{-1}, and recorded an average dressing-out percentage 0.2% greater than the cattle given water (Table 27). This improvement was not enough to warrant the introduction of this electrolyte formula to the lairage area on a commercial basis.

Gortel *et al.* (1992) and Schaefer *et al.* (1990) both recorded significant improvements in the dressing-out percentage of cattle that were provided with an electrolyte solution prior to slaughter, as did Wood (private communication, 1994) (Refer Section 5.1.1 Introduction). As to why Gortel and Schaefer were successful in achieving a significant result in their research, compared to the present study is unclear, but it could possibly be due to the large differences in the experimental methodologies due to this study being conducted in a commercial not a controlled environment. The differences in the methodology between the three studies is shown below:

5.1.5.1 The Difference in the Electrolyte Formulations

The electrolyte formula used in this study attempted to duplicate that used by Gortel, using the sodium concentration as the base electrolyte (ie. Multigro was diluted until the solution had a similar Na^+ concentration to Gortel's electrolyte formula). Gortel's electrolyte solution contained 17.4 $mmol^{-1}$ Na, Multigro at 10 ml l^{-1} contained 18.0 $mmol^{-1}$. The main differences between the two solutions appeared to be in the sucrose and potassium concentrations used, and in the amino acids present in Multigro, compared to Gortel's formula (Table 30).

The importance of the difference in the formulations (Table 30) is not certain, but it is suggested that the failure of the electrolyte solution used in this trial to improve the dressing-out percentage of the cattle cannot be explained by this dissimilarity alone. The difference in the electrolyte solutions is not considered the main reason behind the lack of improvement in the dressing-out percentages because:

(a) there is a lack of available data to suggest why one of these formulas should be better than the other.

(b) there was a lack of reasoning behind the development of the formulas used by Schaefer and/or Gortel that would justify the success they had through the use of their electrolyte formulae alone.

Table 30 : A Comparison of the Electrolyte Formula used by Gortel to Multigro.

mmol l^{-1}	Multigro	Gortel, 1992.
Sodium	18.0	17.4
Chloride	17.8	16.9
Potassium	2.6	10.0
Bicarbonate	2.6	10.0
Magnesium	2.1	4.1
Sulphate	1.1	4.2
Glucose	0.2	274.7
Multigro (10ml/l) *also contained the following amino acids; Analine (3.3 mg/l), Lysine (1.29 mg/l), Phenylanine (1.25 mg/l), Glutamate (4.8 mg/l), Tryptophan (0.42 mg/l), Methionine (1.04 mg/l), Leucine (2.04 mg/l), Isolucine (0.66 mg/l), Valine (1.92 mg/l), Histidine (0.31 mg/l), Arginine (0.1 mg/l), Aspartic acid (4.48 mg/l), Treonine (0.13 mg/l), Serine (0.09 mg/l), Proline (2.06 mg/l), Glycine (0.66 mg/l), Tyrosine (1.2 mg/l), and Cysteric acid (0.01 mg/l) (Coast Biologicals Ltd).*		
Gortel's *formula also contained the following amino acids, each at 250 mg* l^{-1}*, alanine, lysine, phenylalanine, glutamate, tryptophan, methionine, leucine, isoleucine, and valine.*		

Schaefer *et al.* (1990), who first initiated this research, did not provide the reasoning behind the development of their formulation. Gortel *et al.* (1992) similarly, did not explain why their electrolyte formula used was 5 times the concentration of Schaefer *et al's*, yet both recorded improvements in the dressing-out percentages of the cattle used.

Gortel does state in his discussion that, 'the introduction of an electrolyte mixture that is similar in composition to the interstitial fluid appears to be most beneficial to preserving the integrity of the fluid compartments'. Yet Gortel's own formula is not similar to interstitial fluid composition, making it difficult to explain the basis for his assumptions (Table 13). Wood (1994) refers to the World Health Organisation's (WHO) oral rehydration therapy (ORT) formula as the basis for his electrolyte solution, Mitchell (1989), states that the ratio of Na^+ to glucose is important and references the ORT formula of the WHO. Blood (1983) in turn states that an ideal formula to alleviate minor electrolyte and water imbalances is McSherry's solution, which is similar in composition to interstitial fluid. Table 13 provides the formulation for these and several other electrolyte treatments.

Ultimately, there may be an ideal electrolyte formulation, and some formulations may achieve their purpose better than others, this is not refuted. What is being stated here, though, is that the dissimilarities in the four electrolyte formulas that have been referenced (Schaefer *et al.* (1990), Gortel *et al.* (1990), and Wood (1994), and Multigro), is not believed to be the main reason for the differences in the final results between these studies.

5.1.5.2 The Difference In the Temperament of the Cattle Used

The cattle used by Schaefer and Gortel were grain fed, suggesting they were used to a greater level of handling. This leads to the assumption that the cattle used by Schaefer and Gortel would have been a lot quieter than the average animal used in Experiment two.

In trial 2 of Experiment 2, the average ultimate pH of the steers was 6.42 and 6.38[1] in the cattle supplied water and electrolytes respectively indicating the cattle had probably been highly stressed before slaughter. In trial 3, the bulls were observed to become highly agitated prior to transport from the farm. The farm yards had been used the day before to dehorn replacement calves, the subsequent smell of blood making the normally placid animals difficult to handle. Grandin (1993) believes that it is the 'nature' of an animal that plays an important role in the occurrence of stress symptoms in meat. The suggestion is that if an animal is quiet, it will adapt to stressors more readily. If this is correct, then a quieter animal should have lower concentrations of stress response hormones present in its plasma. This theory may explain the large variation in the plasma hormone concentrations measured by Mitchell *et al.* (1989), (Table 8).

The increased level of these hormones within the blood system, indicating the possible activation of the sympatho-adrenal-medullary system (SAMS), may cause a readjustment in the flow of blood around the body of an animal, with the aim to supply energy and oxygen to the major skeletal muscles and organs. The activation of the SAMS may also cause a readjustment in the electrolyte and water balance of an animal as renin and aldosterone are possibly secreted to deal with changes of the homeostatic balance caused by the increased physical activity and the activation of the SAMS. The continued stress that is placed on an animal in lairage, due to its introduction to novel stimuli (Stephens, 1980) and possible water deprivation, will also affect how quickly blood hormone concentration can return to normal.

The inference is that an animal is not in a state of homeostatic balance while its SAMS is active.

5.1.5.3 The Effect of the Difference in the Methodologies

There were substantial differences in the pre-slaughter transportation and lairage facilities used between this study and those conducted by Schaefer *et al.* (1990) and

1 Data provided by the AFFCO kill sheet supplied to the owner of the stock.

Gortel *et al.* (1992). In Schaefer's 1990 study the cattle were transported 200km in 6 hours, giving an average speed of 33km/hr. In lairage, 4-5 animals were placed in a pen 4 m x 7 m. giving a stocking density of 5.6 to 7 m^2 per head. Chopped straw bedding was placed on the floor, and the cattle were held for 18-20 hours prior to slaughter, no mention is made of whether the cattle were washed prior to slaughter.

Gortel *et al's* cattle (*n=65*), were transported for 4 hours (distance not specified), were kept in small pens (area not specified), and also held for 18 -20 hours, this treatment was repeated 6 times in each of the three trial groups, indicating individual group sizes would not have been greater than 4 animals.

This is compared to the methodology used in this present study, where the transportation time ranged from 20 to 45 minutes, the cattle were held on a concrete floor, at a stocking density ranging from 1.54 to 1.92 m^2 per head, for 23 hours. With regards to the stocking density, 5 of the six pens of cattle trialed were held at a stocking density greater than 1.65 hd/m^2. The Ministry of Agriculture and Fisheries (MAF) in their MAF Manual 4 recommends that cattle be held at a minimum stocking density of 1.70 hd/m^2. In England the recommended space allowance in lairage is 2.32 to 2.8 hd/m^2 (Refer to Section 2.5.5.4, pp 38). While stocking density did not effect water consumption, all but one of the stocking densities were greater than 1.70 hd/m^2, suggesting that the effect of stocking density upon water consumption was not adequately studied.

The above recommendations are based on an animal being able to move around a pen freely and allow for adequate access to the water provided. It can clearly be seen that the pre-slaughter handling practises of the overseas researchers differed markedly from those used in this study.

It was suggested that the cattle used in the studies by Gortel and Schaefer were quieter when they reached the lairage area than cattle used in this study. Also due to the different lairage conditions to those used in this study, their cattle had easier access to the fluids provided, and their lairage area was a lot more conducive to rest and recovery.

Cockram (1990), suggested that to improve meat quality in lairage (with reference to DFD meat), a minimum resting period before slaughter should be 6 hours, and from 12-24 hours for fatigued or excited animals. He argued that an animal had to stop using cellular reserves of glucose before the reserves could be replaced. Guilford stated that by not allowing cattle to rest while in lairage, an additional stressor was imposed on them (Private communication).

Therefore it is the suggestion of this study that the reason there was a lack of improvement in the dressing-out percent of cattle in this trial is that the animals were unable to rest adequately enough to allow for the improved rehydration in the muscular tissue of the carcass.

5.1.6 Discussion into the Supply of an Electrolyte Solution

It is important to understand that the carcass of a cattle beast has a maximum amount of water that can be held within the extra-cellular and intra-cellular spaces. The aim of this experiment was to use electrolytes to improve the retention of water in the carcass of a cattle beast at the point of slaughter. This statement assumes that the carcasses of cattle currently supplied 'water only' in lairage have a fluid deficit in their intra-cellular and extra-cellular spaces. The 1-3% carcass weight improvements recorded by Schaefer *et al.* (1990) and Gortel *et al.* (1992) support this theory.

For reasons given in Section 5.1.5 it is suggested that Multigro could not improve the water retention in the muscles of the cattle to which it was provided. This might be because of the provision of a lairage area which did not permit the cattle adequate rest, recovery, and ease of access to fluids prior to slaughter.

In the studies by Schaefer *et al.* 1990, Gortel *et al.* 1992, and the results supplied by Wood (1994), all identified dressing-out percentage improvements. In these three reports all of the cattle involved were held in environments which would have allowed for minimum competition to the fluids provided and permitted the cattle to rest.

The provision of adequate rest in lairage is defined as " providing ease of movement by cattle around a pen, without competition for individual space or to the fluids provided, and the provision of an area that allows the cattle adequate space to sit or lie down without disturbance".

The theory as to why the cattle in this study did not improve their dressing-out percentages suggests that the potential rehydration benefits that the electrolyte solution offered, were countered by the cattle not being able to relax sufficiently to ensure readjustment in their homeostatic mechanism's back to an 'at rest' state. This would then ensure the plasma volume is maintained via the interstitial fluid, rather than from the intracellular spaces. Under these conditions the interstitial fluid volume would then be maintained via the supply of an electrolyte solution.

Rest for an animal is important, and in most cases where rehydration therapies are used it is prescribed as part of the recovery process. In the past, the primary use of fluid therapy had focused upon the restoration of a balanced renal function, through the correction of the fluid deficit in ECF (Mitchell, 1983). These deficits, if allowed to persist have proved fatal to the animals involved, e.g. calves with diarrhoea. In cases like this, the animal is protected from external stimuli, excitement being recognised as extending the recovery process.

5.1.7 Summary

In this study it was presumed that the cattle used were in a state of good health when leaving the farm. If cattle, in this study, did develop a fluid deficit, it possibly arose as a result of time spent without water during transport, followed by possible difficulties in consuming or improving the retention of fluids while in lairage. The potential carcass losses which may have occurred are suspected to be the result of an animal's homeostatic mechanism addressing ECF volume deficits by moving water out of the intracellular spaces.

In this study an electrolyte solution was supplied to cattle in an attempt to increase their uptake of water by allowing for the absorption of Na^+ and water through the villus cells which line the intestine. This is the major route of electrolytes and water into the extracelluar spaces, in effect where Na^+ goes, water and other ions follow. There is also a co-transport system, which operates only when Na^+ and glucose, or particular amino acids are present. By activating this system water can also be absorbed via this secondary route (Hirschhorn and Greenough, 1991). By supplying Na^+ and other ions and amino acids with water, the rate of water absorption into the extracelluar spaces is believed to be enhanced. Gortel *et al.* (1992) suggested that by increasing the volume of fluid held in the interstitial space, an animal will then draw fluid from this reservoir, rather than the ICF, to maintain its plasma volume. If this theory is correct then the result will be a larger amount of fluids being present in the intracellular spaces at the time of slaughter, culminating in an increased dressing-out percentage.

If the above statements are correct, then this may explain why, even with a substantial reduction in fluid intake, the cattle in trials 2 and 3 still achieved marginally improved dressing-out percentages (Table 27). These results suggest that the supply of electrolytes did offer some benefits to the cattle involved. The cattle in trials 2 and 3, of experiment 2, drank 4.6 litres less of the electrolyte solution than they did of water (equivalent to 4.6 kg live weight). While not all water is absorbed into the extracelluar space, this result suggests that the electrolytes did improve the amount of water absorbed into the extracelluar space. Thereby increasing the interstitial fluid volume, and in turn possibly protecting the ICF volume. That the improvement was not greater is suggested to be due to the animals not being allowed adequate rest while in lairage.

It is suggested that this is the reason that Schaefer, Gortel and Wood all recorded carcass weight improvements, because at the time the electrolytes were supplied the cattle were in a much less stimulating environment. In a healthy, rested animal the assumption is that the normal hormonal levels controlling the internal salt and water balances, are operating. It is only in this state that a completely balanced homeostatic state can be achieved.

This thesis accepts the Null hypothesis, that there was no improvement in the dressing - out percentage of cattle supplied an electrolyte solution.

(1) The cattle, whilst in lairage failed to get adequate rest. This in turn meant that the animal's stress response mechanisms, designed to maintain an animal's homeostatic balance, did not allow the animal to achieve a water and electrolyte balance similar to an 'at rest state'.

(2) Secondly, it is suggested that in trial 2 and 3 possible benefits were recorded through the supply of electrolytes, considering the reduced amount of actual solution that was drunk. It is further suggested that this reduced level of intake was the result of the cattle being introduced to a taste that they were unfamiliar with.

CONCLUSION

The supply of an electrolyte solution to cattle, while in lairage, is not feasible in economic terms, given the results of the present study. If, as suggested, cattle need to be rested and in a state of homeostatic balance to repeat the carcass weight improvements recorded by Schaefer and Gortel, then this state is unlikely to occur while the animals are in lairage, without substantial and costly changes to the lairage area of meat plants. These changes being in the form of either substantially lower lairage stocking densities, or the construction of larger holding pens.

Even then, if a carcass weight gain of 2-3 percent can be achieved, the current financial benefits to be gained by the Meat Companies, per carcass, may not be great enough to warrant the investment in a system to supply the electrolyte solution to the cattle. This is because the size of the required capital investment in altering a lairage area plus the cost of establishing the supply of electrolytes into the lairage trough system is a prohibitive cost, given that the majority of the financial benefits to be gained will go to the producer.

Alternatively, if it can be proved that there are substantial welfare benefits to be gained for cattle given electrolytes in lairage, and further that this can be turned into a financial return in the form of improved market access, then the supply of electrolytes to cattle in lairage may need to be re-evaluated.

This is not to say that further research should not be continued into the use of electrolytes to improve the dressing-out percentage of a cattle beast, but it should be conducted with the support of the individuals who stand to receive the greatest financial reward, these being the meat producers (the farmers).

The conclusions of this study are that in order to achieve the gains seen by Schaefer and Gortel, cattle need to be supplied the electrolyte solution in either quiet or familiar surroundings, and where possible the cattle should be given time to adjust to the new taste that the electrolytes provide.

RECOMMENDATIONS

(1) The theory that cattle at rest have an improved chance of increasing their dressing-out percentage through the supply of electrolytes needs to be examined further. The potential financial returns are still there and are large enough to warrant further study in an on-farm situation.

(2) This study assumes that the supply of an electrolyte solution improves the weight of a cattle beast by increasing the water retention of the muscles on its carcass. If this is to be proven correct then future research needs to be able to measure how big is the increase in the water holding capacity of the skeletal muscles.

(3) If this research is continued, it should also look at the benefits of tail-gating livestock that have been supplied the electrolytes, compared to those held overnight in lairage. This will place more responsibility on the producer to prepare their cattle for slaughter. If lairage is creating a problem by reducing the dressing-out percentage of the cattle, then the producer should be aware of this and look for ways to alleviate this problem.

On the industry as a whole, producers need to take more responsibility for their stock prior to slaughter. There is no reason why a producer cannot empty out their animals on the farm, thereby leaving the animals in a familiar, spacious surroundings, for as long as is required before slaughter. Then upon arrival at the meat plant all that is required before slaughter is the inspection by MAF veterinarians and washing. If improved financial returns can be proved through the supply of electrolytes in an on farm situation, then this may be the inducement producers need to introduce this system.

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Appendix 1: Raw Data Compiled in Experiment 2.

Trial 1 : Tuapaka : Bulls : 15/2/94										
Group 1 : Water										
Breed	Tag Number	Carcass Number	Farm Weight	Plant Weight	Fm Wgt-Pl Wgt	Carcass Weight		Pl Wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Fres	60	184	518.0	419.0	27.0	218.4		94.8%	54.3%	57.3%
Sahiwal	3	171	534.0	514.0	20.0	285.6		96.3%	53.5%	55.6%
Fres	33	172	556.0	537.0	19.0	317.2		96.6%	57.1%	59.1%
Fres	No Tag	173	526.0	509.0	17.0	311.0		96.8%	59.1%	61.1%
Fres	29	174	558.0	548.0	10.0	323.8		98.2%	58.0%	59.1%
Fres	40	175	506.0	492.0	14.0	288.2		97.2%	57.0%	58.6%
Sahiwal	9	176	544.0	518.0	26.0	305.6		95.2%	56.2%	59.0%
Sahiwal	4	177	554.0	529.0	25.0	319.4		95.5%	57.7%	60.4%
Fres	39	178	562.0	551.0	11.0	324.2		98.0%	57.7%	58.8%
Fres	10	179	566.0	526.0	40.0	301.2		92.9%	53.2%	57.3%
Fres	57	180	558.0	523.0	35.0	303.4		93.7%	54.4%	58.0%
Fres	56	181	564.0	536.0	28.0	299.0		95.0%	53.0%	55.8%
Fres	6	182	576.0	535.0	41.0	304.0		92.9%	52.8%	56.8%
Fres	43	183	586.0	569.0	17.0	313.8		97.1%	53.5%	55.1%

Trial 1 : Tuapaka : Bulls : 15/2/94 Group 2 : Electrolytes								Group 2 : Electrolytes		
Breed	Tag Number	Carcass Number	Farm Weight	Plant Weight	Fm Wgt - Pl Wgt	Carcass Weight		Pl Wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Fres	55	185	580.0	569.0	11.0	306.4		98.1%	52.8%	53.8%
Fres	53	186	522.0	513.0	9.0	285.8		98.3%	54.8%	55.7%
Fres	58	187	558.0	554.0	4.0	304.0		99.3%	54.5%	54.9%
Fres	14	188	558.0	530.0	28.0	291.6		95.0%	52.3%	55.0%
Fres	49	189	518.0	504.0	14.0	295.8		97.3%	57.1%	58.7%
Sahiwal	16	190	510.0	496.0	14.0	269.4		97.3%	52.8%	54.3%
Sahiwal	20	191	558.0	529.0	29.0	288.4		94.8%	51.7%	54.5%
Sahiwal	12	192	542.0	540.0	2.0	303.2		99.6%	55.9%	56.1%
Fres	24	193	582.0	569.0	13.0	324.8		97.8%	55.8%	57.1%
Fres	51	194	570.0	558.0	12.0	320.0		97.9%	56.1%	57.3%
Fres	26	195	602.0	593.0	9.0	353.8		98.5%	58.8%	59.7%
Fres	23	196	530.0	523.0	7.0	292.0		98.7%	55.1%	55.8%
Sahiwal	7	197	458.0	451.0	7.0	235.0		98.5%	51.3%	52.1%
Fres	34	198	574.0	572.0	2.0	314.2		99.7%	54.7%	54.9%

Trial 2 : Hurley : 2/3/94								Hurley : Trial 2 : 2/3/94		
Group 1 : Water								Group 1 : Water		
Breed	Carcass Number	Tag Number	Farm Weight	Plant Weight	Fm Wgt - Pl Wgt	Carcass Weight		Pl Wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Angus x	112	22	644.0	567.0	77.0	323.8		88.04%	50.28%	57.11%
Hfd	113	17	634.0	586.0	48.0	323.4		92.43%	51.01%	55.19%
Angus	114	1	640.0	606.0	34.0	339.6		94.69%	53.06%	56.04%
Angus x	115	15	600.0	575.0	25.0	313.8		95.83%	52.30%	54.57%
Angus	116	24	648.0	624.0	24.0	349.4		96.30%	53.92%	55.99%
Angus	118	23	650.0	602.0	48.0	356.0		92.62%	54.77%	59.14%
Angus	119	13	664.0	614.0	50.0	355.0		92.47%	53.46%	57.82%
Angus	120	4	644.0	586.0	58.0	350.4		90.99%	54.41%	59.80%
Angus x	121	11	708.0	656.0	52.0	365.8		92.66%	51.67%	55.76%
Angus	122	6	646.0	584.0	62.0	332.0		90.40%	51.39%	56.85%
Angus	123	14	646.0	594.0	52.0	330.4		91.95%	51.15%	55.62%
Angus x	117	25	700.0	661.0	39.0	369.6	D-Rail	94.43%	52.80%	55.92%

Trial 2 : Hurley : 2/3/94 Group 2 : Electrolytes								Group 2 : Electrolytes		
Breed	Carcass Number	Tag Number	Farm Weight	Plant Weight	Fm Wgt - Pl Wgt	Carcass Weight		Pl Wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Angus	125	7	646.0	600.0	46.0	334.8		92.9%	51.8%	55.8%
Angus	126	9	648.0	624.0	24.0	350.0		96.3%	54.0%	56.1%
Hfd	128	8	710.0	644.0	66.0	367.0		90.7%	51.7%	57.0%
Angus x	129	19	682.0	644.0	38.0	366.0		94.4%	53.7%	56.8%
Not Spec	132	10	644.0	637.0	7.0	368.2		98.9%	57.2%	57.8%
Hfd	133	16	670.0	610.0	60.0	346.6		91.0%	51.7%	56.8%
Angus	134	12	648.0	592.0	56.0	331.0		91.4%	51.1%	55.9%
Simm x	135	20	660.0	595.0	65.0	347.0		90.2%	52.6%	58.3%
Angus	124	5	658.0	595.0	63.0	338.8	D-Rail	90.4%	51.5%	56.9%
Angus x	127	3	674.0	639.0	35.0	355.6	D-Rail	94.8%	52.8%	55.6%
Hfd	130	18	644.0	576.0	68.0	326.0	D-Rail	89.4%	50.6%	56.6%
Angus x	131	2	666.0	615.0	51.0	342.0	D-Rail	92.3%	51.4%	55.6%
Hfd	136	21	692.0	615.0	77.0	353.6	D-Rail	88.9%	51.1%	57.5%

Tuapaka : Trial 3 : 15/3/94

Group 1 : Water								Group 1 : Water		
Breed	Tag Number	Carcass Number	Farm Weight	Plant Weight	Fm Wgt - Pl Wgt	Carcass Weight		Pl Wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Sahiwal x	555	145	413.0	385.0	28.0	199.2		93.2%	48.2%	51.7%
Her x Fre	501	154	468.0	459.0	9.0	244.4		98.1%	52.2%	53.2%
Her x Fre	502	143	447.0	425.0	22.0	214.2		95.1%	47.9%	50.4%
Her x Fre	505	150	493.0	451.0	42.0	236.2		91.5%	47.9%	52.4%
Her x Fre	515	147	482.0	457.0	25.0	255.8		94.8%	53.1%	56.0%
Her x Fre	516	155	463.0	434.0	29.0	240.2		93.7%	51.9%	55.3%
Friesian	524	156	524.0	489.0	35.0	258.4		93.3%	49.3%	52.8%
Friesian	526	153	489.0	443.0	46.0	239.6		90.6%	49.0%	54.1%
Friesian	527	151	458.0	432.0	26.0	232.4		94.3%	50.7%	53.8%
Friesian	536	152	456.0	426.0	30.0	216.0		93.4%	47.4%	50.7%
Friesian	537	149	443.0	417.0	26.0	225.6		94.1%	50.9%	54.1%
Sahiwal x	541	142	475.0	432.0	43.0	239.6		90.9%	50.4%	55.5%
Sahiwal x	548	144	421.0	384.0	37.0	218.4		91.2%	51.9%	56.9%
Sahiwal x	550	146	434.0	399.0	35.0	203.6		91.9%	46.9%	51.0%
Sahiwal x	553	148	433.0	396.0	37.0	212.8		91.5%	49.1%	53.7%

Tuapaka : Trial 3 : 15/3/94
Group 2 : Electrolytes

Breed	Tag Number	Carcass Number	Farm Weight	Plant Weight	Fm Wgt - Pl Wgt	Carcass Weight		Pl Wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Her x Fre	507	161	470.0	455.0	15.0	227.8		96.8%	48.5%	50.1%
Her x Fre	508	160	500.0	458.0	42.0	238.0		91.6%	47.6%	52.0%
Her x Fre	509	158	482.0	446.0	36.0	237.4		92.5%	49.3%	53.2%
Her x Fre	511	162	465.0	437.0	28.0	240.8		94.0%	51.8%	55.1%
Her x Fre	518	165	486.0	435.0	51.0	243.6		89.5%	50.1%	56.0%
Friesian	522	166	528.0	469.0	59.0	270.0		88.8%	51.1%	57.6%
Friesian	629	169	481.0	471.0	10.0	247.6		97.9%	51.5%	52.6%
Friesian	530	163	498.0	469.0	29.0	237.0		94.2%	47.6%	50.5%
Friesian	532	159	494.0	464.0	30.0	249.0		93.9%	50.4%	53.7%
Friesian	533	171	506.0	466.0	40.0	239.2		92.1%	47.3%	51.3%
Sahiwal x	543	164	471.0	439.0	32.0	231.4		93.2%	49.1%	52.7%
Sahiwal x	547	168	463.0	426.0	37.0	227.8		92.0%	49.2%	53.5%
Sahiwal x	549	170	433.0	394.0	39.0	218.2		91.0%	50.4%	55.4%
Sahiwal x	551	167	459.0	417.0	42.0	227.8		90.8%	49.6%	54.6%
Sahiwal x	559	157	415.0	392.0	23.0	206.2		94.5%	49.7%	52.6%

Trial 4 : J.Bull : 28/04/94.								Trial 7 : J.Bull : Sample 30 : 28/04/94.		
Group 1 : Water.								Group 1 : Water.		
Breed	Tag Number	Carcass Number	Farm Weight	Plant Weight	Fm Wgt - Pl Wgt	Carcass Weight		Pl wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Angus	6724	96	682.0	644.0	38.0	368.9		94.4%	54.1%	57.3%
Mry Gry	7913	97	674.0	655.0	19.0	380.8		97.2%	56.5%	58.1%
Mry Gry	6501	98	598.0	584.0	14.0	328.0		97.7%	54.8%	56.2%
Simm X	5385	99	632.0	598.0	34.0	345.0		94.6%	54.6%	57.7%
Hfd	952	100	584.0	548.0	36.0	323.2		93.8%	55.3%	59.0%
Charo	2935	101	608.0	579.0	29.0	332.6		95.2%	54.7%	57.4%
Hfd	6294	102	562.0	556.0	6.0	321.4		98.9%	57.2%	57.8%
Angus	6306	105	610.0	575.0	35.0	327.8		94.3%	53.7%	57.0%
Angus	169	106	582.0	525.0	57.0	284.4		90.2%	48.9%	54.2%
Mry Gry	4215	107	594.0	546.0	48.0	306.4		91.9%	51.6%	56.1%
Angus	1776	108	644.0	609.0	35.0	342.0		94.6%	53.1%	56.2%
Angus	6780	109	688.0	657.0	31.0	380.8		95.5%	55.3%	58.0%
Angus	9538	110	576.0	558.0	18.0	319.6		96.9%	55.5%	57.3%

Trial 4 : J.Bull : 28/04/94. Group 2 : Electrolyte.								Group 2 : Electrolyte.		
Breed	Tag Number	Carcass Number	Farm Weight	Plant Weight	Fm Wgt - Pl Wgt	Carcass Weight		Pl wgt as % of Fm Wgt	Cs Wgt as % of Fm Wgt	Cs Wgt as % of Pl Wgt
Simm	6962	111	586.0	576.0	10.0	312.2		98.3%	53.3%	54.2%
Hfd	6456	112	588.0	562.0	26.0	312.4		95.6%	53.1%	55.6%
Angus	464	113	580.0	561.0	19.0	320.4		96.7%	55.2%	57.1%
Not Specf	3904	114	638.0	638.0	0.0	364.4		100.0%	57.1%	57.1%
Angus	n/a	115	582.0	540.0	42.0	301.0		92.8%	51.7%	55.7%
Angus	6849	117	578.0	562.0	16.0	306.0		97.2%	52.9%	54.4%
Hfd	6676	118	642.0	624.0	18.0	360.4		97.2%	56.1%	57.8%
Char	5494	119	590.0	575.0	15.0	330.2		97.5%	56.0%	57.4%
Angus	6530	120	606.0	590.0	16.0	334.2		97.4%	55.1%	56.6%
Angus	5379	121	594.0	571.0	23.0	325.0		96.1%	54.7%	56.9%
Mry Gry	6149	122	604.0	577.0	27.0	330.4		95.5%	54.7%	57.3%
Simm	9555	123	686.0	650.0	36.0	373.2		94.8%	54.4%	57.4%
Mry Gry	6367	124	608.0	579.0	29.0	334.4		95.2%	55.0%	57.8%
Angus	5331	125	678.0	663.0	15.0	354.4		97.8%	52.3%	53.5%

Appendix 2 : Standard Carcass Trim.

Trimming is Limited to:

1. Cod/udder, testes or penis.
2. Fat on ventral abdomen, including precrurial fat.
3. Thick skirt.
4. Xipoid cartilage.
5. Excess fat off brisket (*to within 1cm of underlying muscle*).
6. Intra-thoracic fat.
7. Feet (*between Carpus and Metacarpus*).
8. Neck, extraneous matter only.
9. Head (*between the Occipital bone and the 1st vertebra*)
10. Kidneys and kidney knobs.
11. Channel fat.
12. Tail (*between the Sacral 2nd coccygeal vertebra*).
13. Fat off channel rim.
14. Excess fat off topside rim (*to within 1cm of underlying muscle*).
15. Feet (*between the Tarus and Metatarus*).

Appendix 3 : AgResearch Elemental Analysis of Multigro.

ELEMENTAL ANALYSIS OF SAMPLES BY PLASMA EMISSION SPECTROMETRY

Grasslands Research Centre
Palmerston North
ICP Facility
Analyst: W.Martin
Date:17/3/94
Our Reference:94/76,M1603

Client: MASSEY UNIVERSITY
ATTN: R LUDBROOK
Address of client: PROCESS & ENVIRONMENTAL TECHNOLOGY
PRIVATE BAG, PALMERSTON NORTH

Number of pages in this report: 2

Description of samples: LIQUID MULTIGRO Date samples received:7/3/94

Number of samples: 2
(not including parallel QA)

Number of determinations: 46

Note: (1) The less than sign "<" indicates that the element in that sample had a concentration below the instruments limit of quantitation therefore, the concentration given is the dilution corrected lower quantitative limit for that element.

Unit of measurement: g m^{-3} (µg/g)

TELARC SIGNATORY:

Appendix 3 : continued

Id No.	Sample	Al	As	B	Ca
9	1 SAMPLE	< 2.4	< 2.8	19.5	2109
10	2 SAMPLE	< 2.5	< 2.7	19.1	2098

Id No.	Sample	Cd	Co	Cr	Cu
9	1 SAMPLE	< 0.19	14.4	2.6	154
10	2 SAMPLE	< 0.22	14.2	2.6	154

Id No.	Sample	Fe	K	Mg	Mn
9	1 SAMPLE	271	10260	5257	31.5
10	2 SAMPLE	274	9976	5164	31.0

Id No.	Sample	Mo	Na	Ni	P
9	1 SAMPLE	15.6	42080	< 0.24	129
10	2 SAMPLE	15.4	40852	< 0.25	135

Id No.	Sample	Pb	S	Se	Si
9	1 SAMPLE	< 2.4	3514	< 3.6	< 13.6
10	2 SAMPLE	< 2.5	3480	< 3.8	< 12.3

Id No.	Sample	Sn	Sr	Zn
9	1 SAMPLE	< 0.36	18.1	166
10	2 SAMPLE	< 0.37	18.1	163

Appendix 4 : Statistical Working from Experiment 1 : Reference to Table 16.

Appendix Table 4.1 : The Significance of Water Consumption to the Hours Spent in Lairage.

Dependent Variable : Water (W).

Independent Variable : Hours in lairage (Hour).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	320.45	320.45	6.99	0.033
Error	7	320.77	45.82		
Corrected Total	8	641.22			

Parameter	Estimate	T for HO: Parameter=0	Pr >|T|	Std. error of Estimate
INTERCEPT	-41.518	-2.00	0.086	20.793
HOUR	2.569	2.64	0.033	0.971

Appendix Table 4.2 : The Significance on Water Consumption of the Maximum Daily Temperature.

Dependent Variable : Water (W).

Independent Variable : Daily maximum temperature (C°).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	278.49	278.49	5.37	0.054
Error	7	362.74	51.82		
Corrected Total	8	641.22			

Parameter	Estimate	T for HO: Parameter=0	Pr > |T|	Std. Error of Estimate
INTERCEPT	-30.22	-1.60	0.153	18.86
C°	2.14	2.32	0.054	0.93

Appendix Table 4.3 : The Significance on Water Consumption of the Stock Density while in Lairage.

Dependent Variable : Water (W).

Independent Variable : Stocking density/head (hd/m^2).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	4.20	4.20	0.05	0.84
Error	7	637.02	91.00		
Corrected Total	8	641.22			

Parameter	Estimate	T for HO: Parameter=0	Pr > |T|	Std. Error of Estimate
INTERCEPT	8.157	0.35	0.738	23.420
hd/m^2	3.023	0.21	0.836	14.062

Appendix Table 4.4 : The Significance on Water Consumption of the Combined Effect of the Maximum Daily Temperature and Hours in Lairage

Dependent Variable : Water (W).

Independent Variable's : C°, Hour.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	483.89	241.94	9.23	0.015
Error	6	157.33	26.22		
Corrected Total	8	641.22			

Parameter	Estimate	T for HO: Parameter=0	Pr > |T|	Std. Error of Estimate
INTERCEPT	-66.13	-3.56	0.012	18.564
Hour	2.12	2.80	0.03	0.757
C°	1.69	2.50	0.05	0.678

Appendix 5 : Stastical Tables from Experiment 1 : Reference to Tables 20 to 23.

Appendix Table 5.1 : The Significance of the Effect that Live Weight Loss between Farm and Slaughter had Upon the Dressing-out Percentage of Cattle in Trial 1.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	13.51	13.51	3.00	0.095
Error	26	117.1	4.5		
Corrected Total	27	130.6			
R-Squared	0.103				

Parameter	Estimate	T for HO: Parameter=0	Pr > |T|	Std. Error of Estimate
INTERCEPT	56.18	72.92	0.0001	0.7704
Dr%	-0.0649	-1.73	0.0951	0.0375

Appendix Table 5.2 : The Significance of the Effect that Live Weight Loss between Farm and Slaughter had Upon the Dressing-out Percentage of Cattle in Trial 2.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	31.16	13.16	24.72	0.0001
Error	23	28.99	1.26		
Corrected Total	24	60.15			
R-Squared	0.52				

Parameter	Estimate	T for HO: Parameter=0	Pr > |T|	Std. Error of Estimate
INTERCEPT	55.64	81.87	0.0001	0.679
Dr%	-0.065	-4.97	0.0001	0.013

Appendix Table 5.3 : The Significance of the Effect that Live Weight Loss between Farm and Slaughter had Upon the Dressing-out Percentage of Cattle in Trial 3.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	3.31	3.31	1.20	0.28
Error	28	77.46	2.766		
Corrected Total	29	80.77			
R-Squared	0.041				

Parameter	Estimate	T for HO: Parameter=0	Pr > |T|	Std. Error of Estimate
INTERCEPT	50.67	52.73	0.0001	0.971
Dr%	-0.030	-1.09	0.2829	0.027

Appendix Table 5.4 : The Significance of the Effect that Live Weight Loss between Farm and Slaughter had Upon the Dressing-out Percentage of Cattle in all Trials Combined.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	5246.5	5246.5	19.35	0.0001
Error	81	21962.2	271.14		
Corrected Total	82	27208.7			
R-Squared	0.193				

Parameter	Estimate	T for HO: Parameter=0	Pr > |T|	Std. Error of Estimate
INTERCEPT	176.8	5.38	0.0001	32.85
Dr%	-275.7	-4.40	0.0001	62.69

Appendix 6 : Statistical Tables from Experiment 2 : Reference to Table 26.

Appendix Table 6.1 : Comparing the Significance of the Difference Between the Combined Mean Dressing-out Percentages, Water Vs Multigro

Dependent Variable : Dressing-out Percentage, water (W).

Independent Variable : Dressing-out Percentages, electrolyte (E).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	4.329	4.329	0.51	0.48
Error	75	685.585	8.464		
Corrected Total	77	689.914			

Dressing-out Percentage (LSM)[1]	Std. Error(LSM)	Pr > |T| HO:LSM=0	Pr > |T| HO: LSM(W)=LSM(E)
(W) 52.54%	0.454	0.0001	0.477
(E) 52.18%	0.449	0.0001	

1 Least Square Means.

Appendix Table 6.2 : Comparing the Significance of the Difference Between the Mean Dressing-out Percentages, Trial 1, Water Vs Multigro.

Dependent Variable : Dressing-out Percentage, water (W).

Independent Variable : Dressing-out Percentage, electrolyte (E).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	6.68	6.68	1.40	0.25
Error	26	123.93	4.767		
Corrected Total	27	130.62			

Dressing-out Percentage (LSM)	Std. Error(LSM)	Pr > |T| HO:LSM=0	Pr > |T| HO: LSM(W)=LSM(E)
(W) 55.53	0.583	0.0001	0.247
(E) 54.55	0.583	0.0001	

Appendix Table 6.3 : Comparing the Significance of the Difference Between the Mean Dressing-out Percentages, Trial 2, Water Vs Multigro.

Dependent Variable : Dressing-out Percentage, water (W).

Independent Variable : Dressing-out Percentage, electrolyte (E).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.05	1.053	0.35	0.56
Error	17	50.45	2.968		
Corrected Total	18	51.51			

Dressing-out Percentage (LSM)	Std. Error(LSM)	Pr > |T| HO:LSM=0	Pr > |T| HO: LSM(W)=LSM(E)
(W) 52.49	0.519	0.0001	0.559
(E) 52.97	0.609	0.0001	

Appendix Table 6.4 : Comparing the Significance of the Difference Between the Mean Dressing-out Percentages, Trial 3, Water Vs Multigro

Dependent Variable : Dressing-out percentage, water (W).

Independent Variable : Dressing-out Percentage, electrolyte (E).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.48	0.484	0.17	0.68
Error	27	80.29	2.867		
Corrected Total	28	80.77			

Dressing-out Percentage (LSM)	Std. Error(LSM)	Pr > |T| HO:LSM=0	Pr > |T| HO: LSM(W)=LSM(E)
(W) 49.78	0.437	0.0001	0.684
(E) 49.54	0.437	0.0001	