The animal welfare implications of depriving sheep of feed to facilitate transport and slaughter

Pre-transport standing off for livestock (2009 – 11333)

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By MW Fisher*, PD Muir‡ and NG Gregory†

*Kotare Bioethics, ‡On-Farm Research, and †The Royal Veterinary College

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Strategic Science Team
Policy and Risk Directorate
MAF Biosecurity New Zealand
P O Box 2526
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Telephone: 0800 00 83 33
Facsimile: 04-894 0300

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1. Summary

The animal welfare implications of depriving sheep of feed prior transport for slaughter were studied by reviewing the scientific literature, undertaking a survey of current practices, and monitoring the responses of ewes after varying periods off pasture prior to transport and slaughter.

Few studies have addressed the period of feed deprivation prior to transport (most investigated the effects of fasting whilst in lairage prior to slaughter) or used adult sheep (lambs were most often studied). Many reports focussed on carcass quality (e.g. carcass weight and tenderness). Changes in live weight and gut contents suggest feed deprivation reduces the risk of defecation and urination contributing to the accumulation of effluent during transport and of carcass contamination during processing. However, the point at which that risk is acceptable to transport and processing is unclear. Fasting results in physiological changes indicative of altered metabolism but again it is not clear when those changes are indicative of adaptation to food deprivation or metabolic depletion and compromised welfare. Although the behaviour of sheep in lairage has been described, the significance of the results to animal welfare is unknown.

Two-thirds of farmers surveyed removed their sheep from green feed 3-12 hours before transport for slaughter with some regional variation. The main reasons given for that period of time were to reduce the volume of effluent for transport operators, to prevent wool staining during transport and that sheep were better suited to load and travel empty. Two-thirds of farmers provided sheep with water during feed deprivation. Time off feed could be altered by the requirements of transporters and processors, the weather, and by the class of stock involved although a quarter of farmers never changed their normal protocol.

The behaviour of ewes in lairage after being deprived of food for 0, 9, 18 or 30 hours prior to transport was described as mostly bored and relaxed and least poor or ill-thriven and miserable with no obvious patterns associated with time off pasture. At slaughter, increasing time off pasture prior to transport resulted in no change in serum glucose but in increasing concentrations of free fatty acids, β-hydroxybutyrate, triglycerides and urea indicative of increasing mobilization of body reserves. Different periods of feed deprivation had no significant effect on carcass weights (mean 22.7 kg) or dressing out percentages (mean 40.9%). Carcass contamination was limited to >200 plate counts on 8/20 carcasses from ewes fasted for 9 hours (few carcasses had detectable coliforms). Meat ultimate pH was unaffected by the period of feed deprivation but meat became darker and had reduced redness with increasing time off feed. The results suggest that sheep in variable body condition adapted to the periods of feed deprivation by mobilizing their energy reserves without any evidence of metabolic depletion (e.g. depleted blood glucose or high meat pH).

While hunger is difficult to quantify, the results of this study suggest that 4-12 hours off pasture or green feed prior to transport would not be expected to unduly compromise the welfare of adult sheep transported for slaughter.

2. Introduction

Handling and transporting animals for slaughter at locations distant from farms is an inevitable consequence of urbanization and the centralisation of meat processing. Handling and transportation can impact on the welfare of the animals through factors such as the quality of stockmanship, social disturbance, exposure to any novel and adverse conditions, and fear, fatigue, injury and motion sickness (Gregory 1998; Cockram 2007; Ferguson 2007; Broom 2008; Terlouw et al. 2008; Ferguson and Warner 2008; Fisher et al. 2010a; Warriss 2010; European Food Safety Authority 2011). The removal of feed, and sometimes water, from animals presents a more inherent compromise (Hogan et al. 2008, 2009).

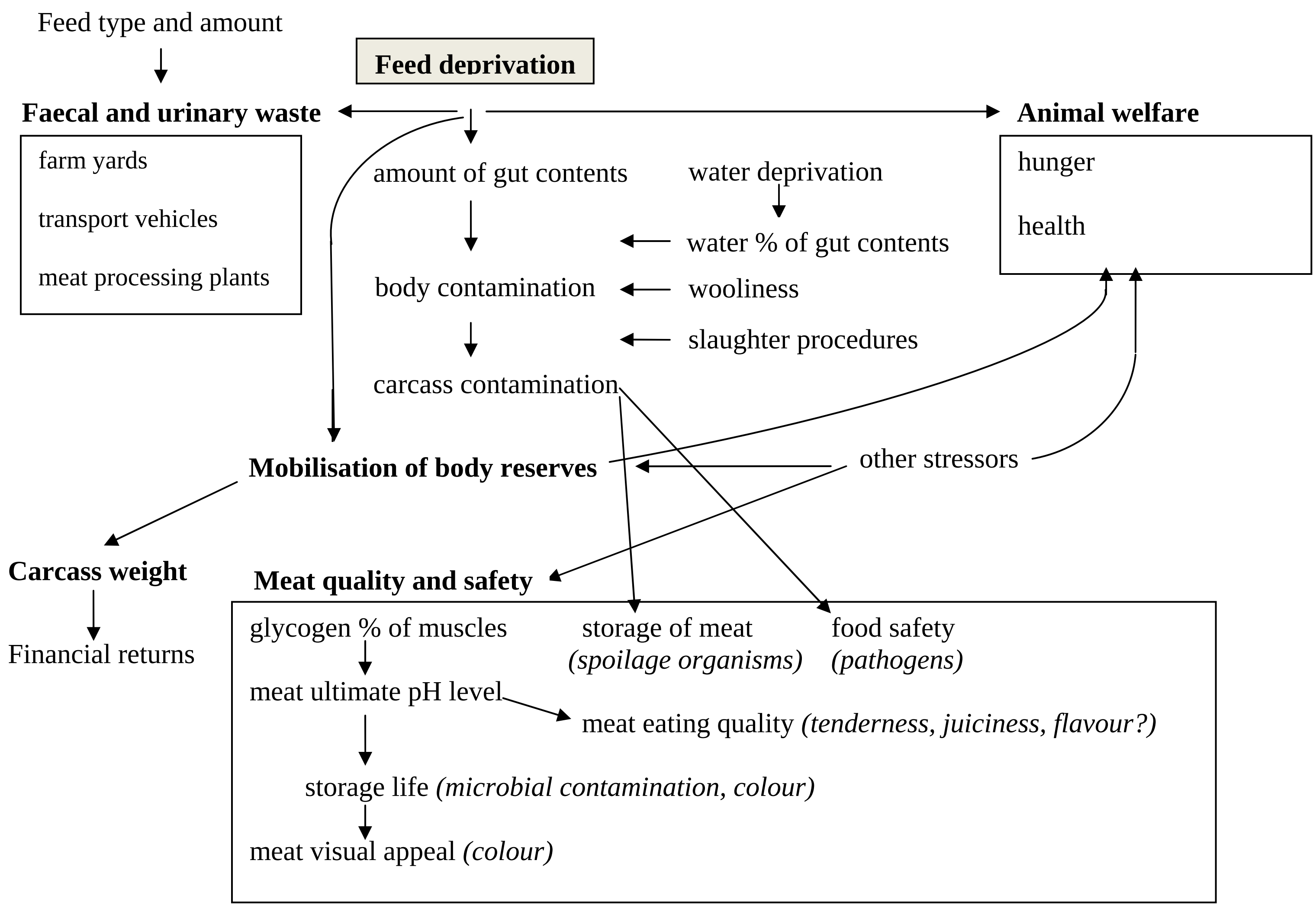
Food and water deprivation usually commences prior to transport to empty the gastrointestinal and urinary tracts to reduce defecation and urination. This reduces the accumulation of effluent during transport, and the risk of carcass microbial contamination during slaughter (Grau and Smith 1974; Biss and Hathaway 1996; Hadley et al. 1997), and it facilitates more hygienic evisceration (Petersen et al. 1981).

While many aspects of the welfare of sheep during transport and slaughter have been extensively studied, evaluation of feed withdrawal has focused mainly on live and carcass weight loss and meat quality defects (e.g. Kirton et al. 1968; Thompson 1987) and on the effects of reduced muscle glycogen on meat tenderness (e.g. Warriss et al. 1987). However, animal welfare is not simply a measure of how well an animal performs or even what it experiences, and with animal welfare increasingly being determined in the public sphere (see Fisher 2009), the effects of feed deprivation need to be viewed from an integrated perspective.

There are around 4.8 million adult sheep killed annually in New Zealand (MAF 2010), after being transported from less than 100 km to up to 400-500 km (see Fisher and Jones 2008). Feed deprivation not only potentially affects their welfare through the need to mobilise body reserves, but also effluent accumulation during transport and processing, the financial returns to producers from carcasses, and meat quality and safety (Figure 1). The first part of this report reviews the scientific literature and presents the results of a survey of sheep and sheep and beef farmers to determine the range of practices being used within the New Zealand sheep industry. Although this information has long been requested (e.g. Kirton et al. 1965) to our knowledge it has not previously been collated.

The second part of the study reports on research investigating the animal welfare effects of pre-transport standoff periods in adult sheep. Animals with low digesta loads may be compromised more by the effects of feed and water deprivation (Hogan et al. 2007). Cull animals, such as ewes, and especially those in poorer condition or health, may be most at risk of welfare compromise since, and depending on the market, availability of killing space, especially during the main slaughter season, means these stock classes may sometimes be held on farms awaiting slaughter. When feed is limited on those farms, it is more likely to be allocated to other higher value classes of livestock, e.g. lambs, steers and bulls.

Figure 1. A summary of some of the interactions between feed deprivation in sheep and effluent accumulation, mobilisation of body reserves, animal welfare, financial returns from carcasses and meat quality and safety (from AR Bray unpublished data).



3. The effects of feed deprivation and transport in sheep

3.1. A REVIEW OF THE SCIENTIFIC LITERATURE

3.1.1 Physical changes

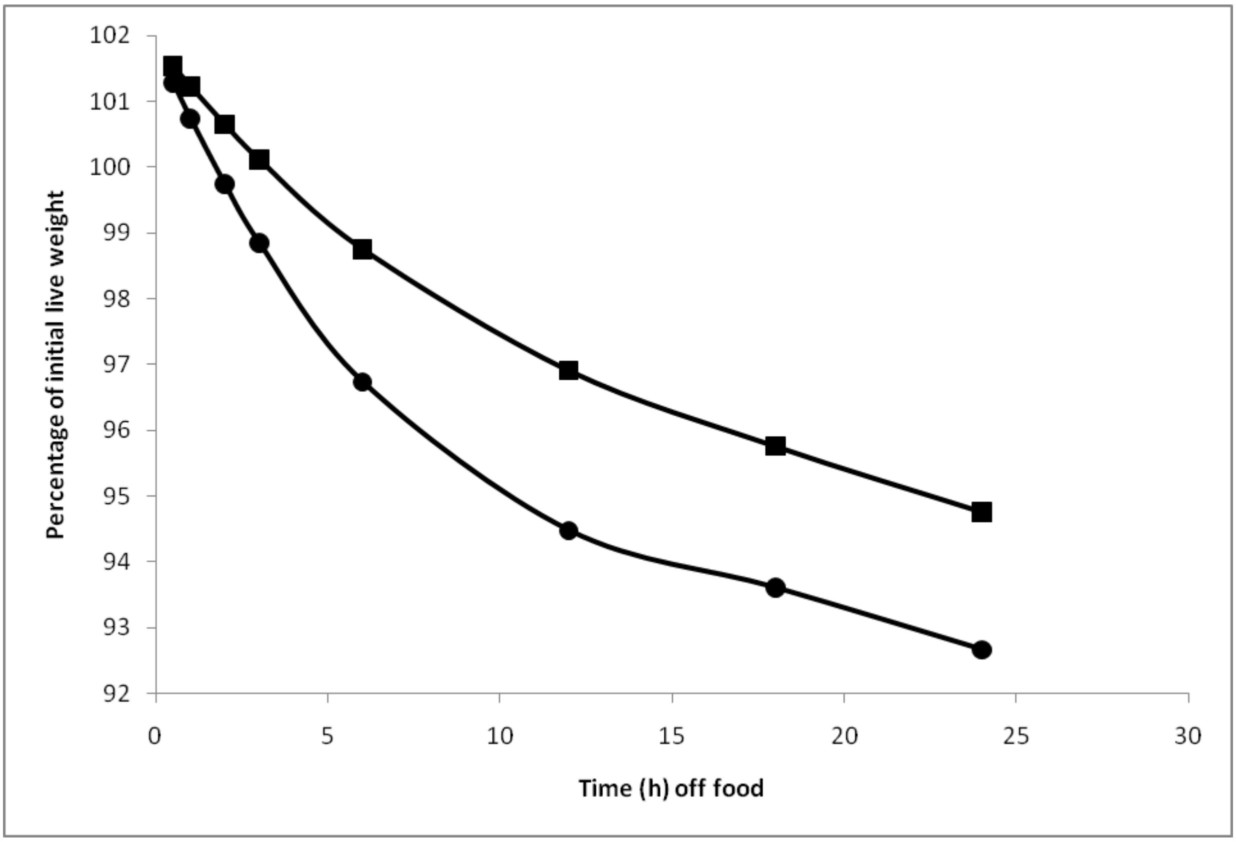
Pre-slaughter fasting principally reduces the contents of the gastrointestinal tract and the weight of the liver. The gut contents of sheep weighing an average of 58 kg and fed hay and concentrates accounted for 19% of their live weight (Boyne et al. 1956). Most of the contents were in the reticulo-rumen (7.75 kg), large (1.32 kg) and small (0.93 kg) intestines, and the abomasum (0.91 kg). However, the quantity of rumen contents can be affected by the age and physiological status of the animal, its diet, and the time of day (fasting early in the morning is likely to result in less excreta than later in the day – Hogan et al. 2007). Most (56%) of the 1.7 kg of weight lost within the first 24 hours of fasting by lambs previously fed a diet of concentrates, was in gut contents (0.95 kg), more than half of that (0.53 kg) from the rumen, with 0.11 kg from the liver (Warriss et al. 1987). After 3 days of food and water deprivation, the 7.1 kg loss in live weight experienced by mature, 72 kg wethers was made up of 80% water and 20% solids. These changes comprised gut contents (28.1%) and gut tissues including the liver (6.7%) with the remaining 65% from other tissues, presumably blood, adipose and muscle (Cole 1995).

The decrease in gut contents has been reported in a number of studies (e.g. Kirton et al. 1968; Petersen et al. 1981; Warriss et al. 1987). In cull ewes, the weight of reticulo-rumen contents averaged 4.81 kg when held in lairage without food for 24 hours and 3.79 after 48 hours (compared with 4.49 kg when slaughtered upon arrival after an estimated 12-24 hours without food and water associated with routine handling and transport). The contents were generally of a semisolid nature immediately after transport (10.32 g dry matter per 100 g of reticulo-rumen contents) but, and unlike lambs who tended not to drink, they became more fluid (5.95 g after 24 hours and 5.10 g per 100 g of reticulo-rumen contents after 48 hours) during fasting with access to water (Petersen et al. 1981).

Loss of live weight occurs most rapidly in the first 12-24 hours of fasting and/or transport, after which the rate of loss tended to reduce (Kirton et al. 1968; Thompson et al. 1987; Cole 1995; Knowles et al. 1995; Burnham et al. 2009) or remain constant (Kirton et al. 1971; Warriss et al. 1987; Burnham et al. 2009). Not surprisingly, the rate of liveweight loss is affected by a range of factors such as animal fatness (lambs with a higher fat score had a lower percentage rate of liveweight loss – Thompson et al. 1987) and feed digestibility (rate of liveweight loss was faster in lambs fed highly digestible compared with poorer quality and drier feeds – AR Bray, unpublished data).

While many studies involve lambs, Burnham et al. (2009) described weight loss in mature, mid to late pregnant ewes (and wether hoggets) fasted during winter but without being transported (Figure 2). Liveweight loss was most rapid initially but then slowed with losses averaging 7-10% of live weight over 24 hours, similar to that reported in lambs (e.g. Kirton et al. 1968; Thompson et al. 1987; Warriss et al. 1987).

Figure 2. Changes in live weight in mature pregnant ewes following food and water deprivation during winter (July and August) at about either 70 (■, July) or 130 (●, August) days of pregnancy derived from equations described by Burnham et al. (2009).



3.1.2 Physiological changes

Fasting also results in changes in energy metabolism (Figure 3). Metabolic energy normally derived from glucose or from the oxidation of volatile fatty acids produced in the rumen, is replaced by energy produced from mobilised body fat. The liver of lambs killed immediately off pasture weighed on average 576 g compared with 484, 413 and 349 g after 1, 3 and 7 days fasting, respectively (Ilian et al. 2001). As a result, food deprivation can result in a rise of circulating free fatty acids, β-hydroxybutyrate and urea, and in a progressive depletion in liver and muscle glycogen (Warriss et al. 1987; Knowles et al. 1995). β-hydroxybutyrate was the only metabolite which progressively increased with longer periods of fasting in pasture-fed lambs (Warriss et al. 1989).

Figure 3. The main characteristics of the different phases of energy metabolism in feeding and fasting in sheep (upper panels; collated from various reports, especially Bassett 1974; Knowles et al. 1995; Gregory 1998), and some of the corresponding biochemical changes in lambs removed from pasture for 0-72 hours and transported 2 miles to slaughter (lower panel; redrawn from Warriss et al. 1989).

Feeding

Energy is derived from volatile fatty acids produced in the rumen by microbial digestion of cellulose or other complex carbohydrates. The main volatile fatty acid, acetate, provides approximately 70% of the caloric requirements. Glucose is also produced from the rumen and any excess is stored as fat.

Cessation of feeding – mobilisation of liver glycogen

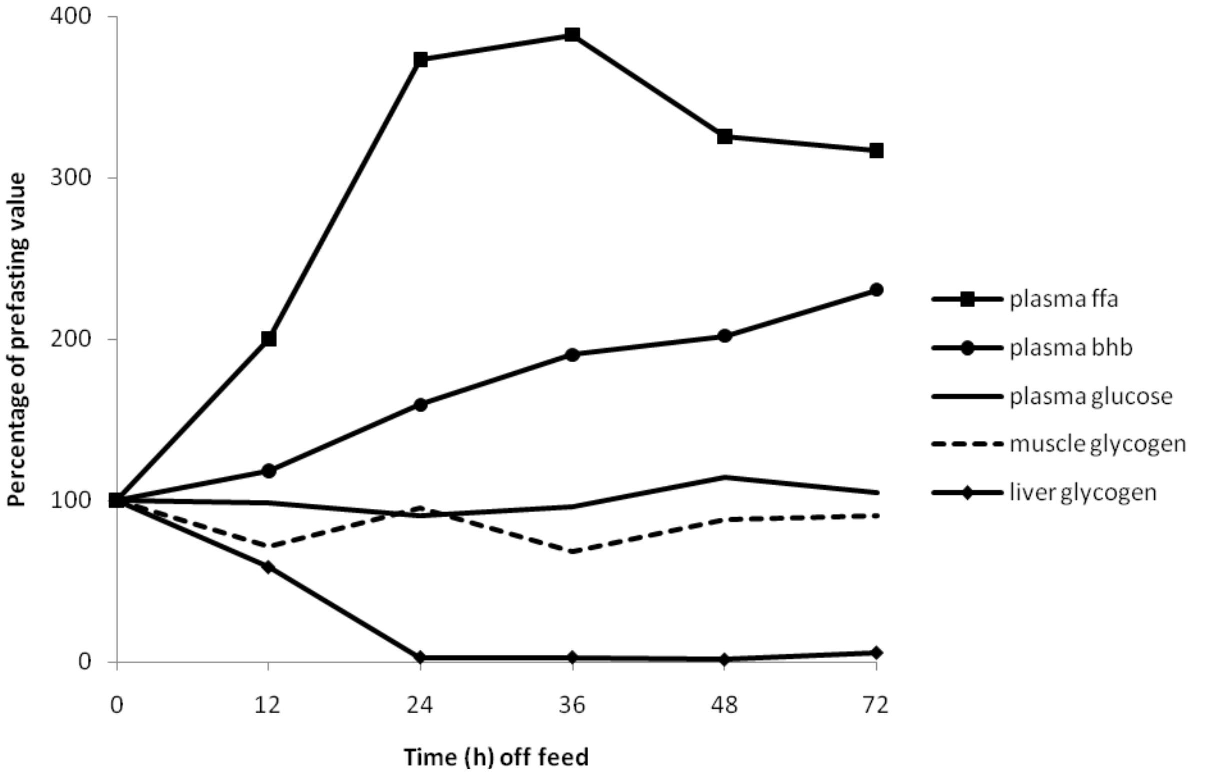
Acetate remains the main source of energy until rumen production slows and circulating acetate concentrations fall. Glycogen from the liver becomes the main source of energy until depleted after about 24 hours.

Fasting – mobilisation of fat reserves

Energy is derived from triglycerides, free fatty acids (ffa) and, if hypoglycemic, β-hydroxybutyrate (bhb), as fats stored in adipose tissue are broken down. Circulating concentrations of these two substrates rise. High ultimate pH may indicate glycogen depletion from muscle.

Prolonged fasting – mobilisation of protein (muscle)

Energy is supplemented from the breakdown of protein in muscle into amino acids, reflected in a rise of blood urea and plasma glutamate dehydrogenase and in a loss of carcass weight.



Changes in energy metabolism, especially in the mobilisation of body reserves (Figure 3), have been used to infer hunger, which is an animal welfare compromise, but it should be noted that, at least initially, these metabolites reflect normal homeostatic changes as the animal adapts to its altered nutritional circumstances. Although the regulation of food intake in ruminants is complex (Baile and Forbes 1974; Bassett 1978; Roche et al. 2008), circulating volatile fatty acid concentrations, amino acids and lipids are thought to be the nutrients most likely to stimulate hunger and satiety regulatory mechanisms (Roche et al. 2008). However, the period at which hunger becomes substantially worse has not been identified (Gregory et al. 2009) principally because hunger is not well understood, at least in scientific terms (Lawrence et al. 2004).

Environmental factors such as exposure to cold temperatures and handling also produce metabolic changes (e.g. Slee and Halliday 1968; Halliday et al. 1969) and it has been suggested that there may be seasonal and/or dietary differences in the ability of some sheep to sustain fat mobilisation. Adult sheep metabolically adjusted to laying down fat during seasonal periods of available green pasture may be less able to use their fat reserves during prolonged inappetance associated with sea transport compared with those mobilising their fat reserves during seasonal periods of dry pasture availability (Higgs et al. 1991; Richards et al. 1991). How sensitive other sheep, e.g. lambs and those selected for leanness, are to these influences is unknown.

Handling and transport for slaughter may also mean a period of water deprivation and several studies have investigated dehydration and by inference thirst (e.g. Lowe et al. 2002; Jacob et al. 2006a, b). Forty-eight hours without water increased liveweight loss, but not carcass weight loss, in lambs (Jacob et al. 2006a). Although the rumen contains 10-25% of body water (Hecker et al. 1964) the extent to which it buffers against the sensations of hunger and thirst is considered unknown (Dwyer 2008). Plasma volume is unaltered during the first two days of water deprivation (see Cockram 2007) although, at least in Australia, lambs can be sub-clinically dehydrated at the time of slaughter (Jacob et al. 2006b). Plasma glucocorticoid (e.g. cortisol) concentrations are frequently used as an indicator of acute stress in animal welfare studies. However, glucocorticoids are also involved in the metabolism of carbohydrate and fat metabolism in response to fasting. Consequently, concentrations are generally or relatively unchanged by food deprivation (e.g. Bassett 1968, 1974; Parrot et al. 1996; Cockram et al. 1999), or perhaps elevated by the novel or psychological nature of fasting (Purchas, 1973).

3.1.3 Behavioural changes

The above physiological measures are indirect indicators of an animal's welfare and behaviour may provide a useful complement to help understand what it is experiencing (Lawrence et al. 2004). Behavioural signs of hunger and/or thirst may confirm physiological measures provided the latter are not compromised by coincident psychological stressors. Although some aspects of the behaviour of sheep during transport and in lairage have been described (e.g. Jarvis and Cockram 1995; Cockram et al. 2004) there are no studies investigating the effects of the duration of pre-transport fasting. The usual priority of sheep following transportation is to feed, drink as a consequence of feeding if it is high dry matter feed, and only later lie down (Cockram et al. 1999).

Fatigue associated with transport of livestock is relatively unknown and there is no evidence for motion sickness in sheep (Earl 2007). However, it has been claimed that "sheep have been observed to show some form of this condition" (Daunton 1990). Other reports suggest that compared with man and dogs, other species including sheep and cows, have "a lesser but unequivocal susceptibility" to motion sickness (see Money 1970). Although ruminants do not readily vomit they can experience 'internal vomiting' (shunting of abomasal and duodenal contents towards the rumen) but this has not been demonstrated in the context of motion sickness. Perhaps transport operators are best placed to comment on travel sickness in livestock. For example, it is held that dairy cows are more likely to sit down during travel if having been recently fed. Similarly, slippery excreta on truck floors may contribute to livestock losing their balance during transport (Ferguson 2006).

3.1.4 Pathological changes

The final measure of the welfare of animals is the incidence of injuries and deaths associated with fasting and transport – there are apparently no reports although mortality amongst lambs appears very low (0.0182% in the UK – Knowles et al. 1994). Although there is no comparable data available for New Zealand, it is suggested that the incidence of serious injuries and deaths is likely to be too low to ascertain any effects of different standoff periods. The incidence of lesser injuries such as bruising (Petersen 1978) may be a more useful indicator.

3.1.5 Effects of transport

Metabolic changes may be exaggerated by the additional energy demands during transportation associated with maintaining posture in a moving vehicle and thermoregulation in unfavourable conditions (Lawrence et al. 2004). Studies with lambs which have separated the effects of fasting alone from the combined effects of fasting and transport have generally been unable to demonstrate that transport is a significant additional stressor (Knowles et al. 1995; Broom et al. 1996; Warriss et al. 1990) while others suggest transport exacerbates the fasting liveweight loss (Thompson et al. 1987; Horton et al. 1996). Similarly, it has been suggested that the effects of fasting in cattle are not the same as fasting combined with transportation (Galyean et al. 1981; Cole et al. 1986).

3.1.6 Fasting and carcass quality

There are several different dimensions of carcass quality ranging from storage life and meat eating qualities, to food safety and microbial contamination. The effect of food deprivation on the rumen and its microbes (see Mackie et al. 2002) depends on the amount and composition of plant material in the rumen when fasting commences – animals grazing high quality pastures have less rumen contents, and which would be removed more quickly, than animals fed mature low quality roughage (Hogan et al. 2008). Food deprivation affects the number and composition of bacteria in the rumen, with many dying through a lack of readily digestible nutrients when the animal is deprived of food. However, some bacteria which can derive nutrients from cellulose survive since some plant material remains in the rumen. The normal population of rumen microbes appears to control the numbers of potentially pathogenic bacteria (including Clostridium, Salmonella, Escherichia coli) but when deprived of feed for short periods (as little as six hours), there is less control over the growth of pathogenic microbes in the gastrointestinal tract with implications for sheep and human health (Hogan et al. 2007; Rostagno 2009). These effects are time and diet dependent – 24 hours of food deprivation, or a diet of concentrates, resulted in significantly more rumen E. coli, coliform and enterobacteria compared with 12 hours of fasting, or a diet of hay (Gutta et al. 2009). Microbiological contamination of carcasses, especially those from dirty and woolly animals, has been well documented (e.g. Biss and Hathaway 1995, 1996; Hadley et al. 1997). Fleece and carcass contamination increased with time off feed and the degree to which earth-floored, abattoir pens were contaminated (Grau and Smith 1974), possibly reflecting the period of exposure to contaminants rather than of feed deprivation. While farm standoff environments vary, they are generally unlikely to resemble the more hygienic abattoir conditions of the present day.

Tenderness and colour are the best documented indicators of meat eating and storage quality and are mediated by muscle pH and affected by the level of glycogen in the muscle. Pre-slaughter stressors reduce muscle glycogen (Bray et al. 1989; Hogan et al. 2007) producing meat with intermediate or high ultimate pH. Intermediate ultimate pH meat is also tough and dark while high pH meat is dark and more likely to spoil through microbial proliferation. Longer holding periods at abattoirs, and by inference longer fasting periods, in addition to those already imposed during handling and transport, were significantly correlated with higher ultimate pH meat values (Petersen 1984). However, short-term feed deprivation has been found to have little effect on meat quality (e.g. George et al. 1968; Kirton et al. 1971; Warriss et al. 1987). Moreover, 1 day of fasting was associated with a significant improvement in meat tenderness in lambs compared with 0, 3 and 7 days of fasting (Ilian et al. 2001).

While the effects of preslaughter stress, including food deprivation, on meat quality are evident in meat pH and have been well documented, the non-pH-mediated effects, such as water-holding capacity and purge loss, are less well known (Ferguson and Warner 2008). Meat yield is also affected by fasting. Seventy-two hours of fasting significantly reduced the meat content in lambs (e.g. weight of the leg, loin, or shoulder, weight of the breast, flank and shank) as well as liveweight, carcass weight and dressing out percentage when compared with 12 hours of fasting (George et al. 1966; Kirton et al. 1967). Similarly, Thompson et al. (1987) estimated that lambs lost 0.54, 0.93, 1.15 and 1.21 kg of carcass after 24, 48, 72 and 96 hours of fasting, respectively.

3.2. CURRENT PRE-SLAUGHTER STAND-OFF PRACTICES

3.2.1 Survey methods

A telephone survey of 800 New Zealand farmers, of which 122 farmed sheep and 364 sheep and beef, was undertaken by Cinta Research Ltd (Tikokino, Hawkes Bay) between 1 March and 13 April 2010. Respondents were randomly sourced from a Cinta Research database of individuals, mainly male and mainly over 50 years of age, and spread across New Zealand. They were contacted by rural interviewers, many of whom were involved in farming. Interviews were conducted with the person who makes policy decisions for the farm. To be included in the survey, farms had to be more than 100 hectares unless predominantly a dairy unit.

The questions focused on respondents' normal practices around preparing stock for transport to slaughter by standing them off pasture or crop other than hay. Respondents were informed that the work had been commissioned by MAF to inform animal welfare recommendations and ensure that research reflects current practices. The questions asked were: (1) When you send sheep for slaughter, on average how many hours would you say the stock are usually off green feed including pasture or crops, other than hay, before they are loaded?; (2) For your farming situation, can you please tell me the reasons why you keep the sheep off green feed including pasture or crops, other than hay, for that period of time before loading them?; (3) Can you tell me the yard or paddock environment the sheep are held in whilst off green feed including pasture or crops, other than hay, and what is provided or the sheep have access to during this period before they loaded?; (4) Please tell me the different situations where you may change your normal protocol and have the sheep off pasture or crop feed for a longer or shorter period prior to sending for slaughter?; and (5) Now if the sheep are going to other destinations for example the sale yards or another farm – on average how many hours would you say the stock are off pasture or crop before they are loaded? In addition, demographic data was sought on the region, farm type and area, gross income, gender and age. The margin of error was ± 2.8 % with a 95% level of confidence.

3.2.2 Survey results

Most survey respondents (65% - see Table 1) indicated sheep were removed from green feed for 3-12 hours prior to transport for slaughter (transport to other destinations showed a similar, perhaps slightly earlier, pattern). The reasons given for these practices were to reduce the volume of effluent for transport operators (stated by 37.2% of respondents); to allow sheep to empty out to prevent wool staining during transport (37%); because sheep were better suited to load and travel empty (36.5%); it was required because of meat processor contractual obligations (20.9%); to reduce the impact of transport on carcass contamination and meat quality (12.2%); and/or it best suited truck arrival time (10%). Sheep were mostly held in a bare yard or shed (52.1%) or on limited pasture (37.8%). Water was usually available (66.9%) but not shade (8.1%). While 25% of respondents indicated they never changed their standoff protocol, most did use longer or shorter periods due to the requirements of the transport company (23.1%); stock being picked up early in the morning (17.3%); processor contractual requirements (10.9%); adverse weather (8.1%) or different classes of stock, e.g. weaned lambs (5.8%).

Table 1. Average duration of time sheep are reported to be held off green feed, including pasture and crops other than hay, before they are loaded for transport.

(a) Distribution of standoff periods in sheep going to slaughter or other destinations

Time (h) off green feed	Slaughter (%)	Other destinations (%)
0	2	5
1	6	10
2	13	15
3-6	34	26
7-12	31	22
13-24	13	7
25-48	<1	1
Don't know/not applicable	1	13

(b) Regional variation in the average periods sheep are held off feed prior to transport for slaughter. Means are approximate only, where necessary calculated from a mid-point value of 4.5, 9.5, 18.5 and 36.5 for the 3-6, 7-12, 13-24 and 25-48 hour categories used in the survey.

North Island region	*n*	Approximate time (h)	South Island region	*n*	Approximate time (h)
Northland/Auckland	26	4.0	Nelson/Marlborough	26	7.4
Waikato	35	4.5	West Coast/Tasman	4	3.5
Bay of Plenty	19	3.9	Canterbury	82	9.0
Gisborne	28	5.5	Otago	69	11.4
Hawke's Bay	36	4.2	Southland	55	13.3
Taranaki	15	5.9			
Manawatu/Whanganui	43	4.1			
Wairarapa/Wellington	30	4.1			

3.3. DISCUSSION

The removal of livestock from feed for short periods prior to transport has two broad and relevant parameters. First, there is likely to be a minimum period required to achieve a satisfactory level of emptying out to facilitate transport and reduce the risk of contamination at slaughter. Second, there will be a maximum period defined by animal welfare, principally hunger, and the risk of adverse effects on carcass quality. Both the minimum and maximum periods of removal from feed are likely to be influenced by factors such as age, species and class of animal, season and climate, as well as on-farm practices, while the maximum period is also influenced by transportation (especially distance/duration and quality). In other words, pre-transport fasting is part of a multi-factorial system.

The scientific literature, although tending to focus on longer periods of fasting more indicative of the whole mustering, yarding, transporting and lairage process, highlights early losses due to a reduction in gut fill and excretory losses followed by a later reduction in carcass weight associated with dehydration and the mobilisation of energy (mainly in the form of liver glycogen) for maintenance. Pre-slaughter stress may also contribute to the animal shedding pathogenic microbes, while post-mortem the muscles fail to acidify because of depleted glycogen and ultimate pH remains high or intermediate contributing to inferior meat. Furthermore, food deprivation-induced changes in rumen pH levels may favour potentially pathogenic bacteria in the gut.

Feed deprivation, or fasting, and transport and its associated stressors (e.g. water deprivation, handling, unfamiliar environments, and exposure to changing thermal environments) are each potential stressors on their own. However, livestock are invariably exposed to more than one type of stress since animals are usually deprived of food for variable periods prior to transport and then do not have access to feed during transport and whilst in lairage at the abattoir. While some studies have, for example, minimized the impacts of transport by maintaining sheep in paddocks adjacent to abattoirs (e.g. Kirton et al. 1968; Thompson et al. 1987; Warriss et al. 1989), or subjected animals to different periods of fasting whilst in lairage (e.g. Kirton et al. 1971; Petersen et al. 1981), fasting has usually been imposed after considerable disruption to the animals' routine. There have been few studies where different periods of food deprivation have been imposed prior to routine transport, lairage and slaughter.

Much of the literature on the effects of fasting involves relatively long periods of deprivation, typically 24 to 72 hours, and considerably longer than the recommended 4-8 hour standoff period prior to transportation (Anonymous 2003). Furthermore, adult ewes appear to tolerate up to 48 hours of transport without feed without undue compromise to their welfare (Fisher et al. 2010b). It might therefore be expected that relatively short periods of pre-transport food deprivation would have few effects other than predisposing animals to the fatigue of transport. There is little information regarding fatigue and tiredness in sheep. Morag (1967) described fatigue and exhaustion in animals unable to ruminate because they were fed a finely-ground diet. Signs included panting, lethargy, lying unusually prone with head stretched out between forelegs, generally unresponsive to disruption and sleeping deeply (ruminants rarely show profound sleep). In one study sheep did not appear to be physically tired after 15 hours of transport (Cockram et al. 1999). While it could be argued that hunger may subdue the expression of tiredness, studies in cattle indicate few impacts of pre-transport fasting on animal welfare (Earley et al. 2006) and meat quality (Lively et al. 2009). Dehydration and metabolic depletion have been noted in cull cattle and water buffalo when deprived of food and water and transported for much longer periods (possibly up to two weeks) than occurs in New Zealand (Alam et al. 2010).

Despite considerable literature on the effects of feed deprivation in sheep, it is important to acknowledge its limits within the overall context of the current research programme. Firstly, much of the literature deals with lambs, there being few studies undertaken with adult sheep or ewes. While there are obvious similarities (e.g. comparable proportions of live weight loss after 24 hours of fasting), there were also differences, albeit of unknown importance – e.g. ewes drank more in lairage than lambs (Petersen et al. 1981) and had slightly lower free fatty acid turnover during fasting (Hileman et al. 1990). Secondly, the literature describes animals fed a range of diets, e.g. fresh or green pasture, hay and concentrates. Diet, as well as a myriad of other factors such as physiological state and environmental factors, is acknowledged as having an important influence on ruminant metabolism and welfare. Finally, and most significantly, there are apparently no relevant studies describing the effects of different periods of pre-transport feed deprivation on the welfare of ewes sent for slaughter, or the quality of their carcasses (microbial contamination, meat colour and tenderness etc).

Most (65%) survey respondents indicated sheep were removed from pasture for 3-12 hours prior to transport for slaughter (the slightly longer periods in southern regions reflecting anecdotal industry beliefs that stock in the south are held off feed for longer). This result compares with the 4-8 hour period recommended in the transport effluent guidelines (Anonymous 2003) suggesting respondents were largely meeting the guidelines, if only just. The approximate mean standoff periods were closer to the minimum 4 hours in most parts of New Zealand (Table 1). Alternatively, respondents may have been answering according to the recommended guidelines rather than actual practices. It is acknowledged, as in any survey, that respondents may supply what they think is the 'right' answer, especially if they are conversant with industry guidelines. However, what is also revealing is that while 25% of respondents indicated they never changed from their protocol, many did. Transport and processor company requirements accounted for 44% of the instances where farmers changed their routines; early morning loading, adverse weather and class of stock accounting for a further 31%. This could be interpreted as that while farmers 'follow' the guidelines, or at least want to, they are unable or choose not to. This interpretation is supported by recent transport industry findings that a proportion of livestock are not adequately prepared (Road Transport Forum New Zealand 2010; Longmore 2010). A more comprehensive survey would need to explore any differences between reported and actual standoff times, the circumstances behind any divergence such as inadequate notification of loading times, and the ways in which farmers modify their practices due to those circumstances.

The apparent tension between transport and farming industries regarding appropriate standoff periods is complex and unlikely to be completely solved by apportioning blame (e.g. see Longmore 2010). The transport of animals from farm to processor represents the interface of two worlds – the former susceptible to the practical constraints of animal husbandry, climate and even available daylight hours, the latter shaped by requirements for efficient industrial plant operations. It is clear that transporters and processors have a difficult job in ensuring continuity of supply of livestock for slaughter, just as farmers have difficulty in preparing stock for transport with minimal notice. These conclusions raise a number of questions with possible repercussions for the welfare of the animals involved. If animals are being transported outside the guidelines, are the guidelines justifiable? If the main issue with pre-transport standoff periods is the accumulation of effluent during transport, should it not be addressed by investigating the adequacy of, for example, effluent collection and disposal facilities? If stock can be transported after relatively short periods off pasture, then emptied out in lairage to minimise risks to carcass hygiene, would this not reduce the period many animals are deprived of food prior to slaughter? Because of a lack of information about the welfare of sheep held off feed prior to transport for slaughter, the current research programme may well indicate opportunities for all parties to better orchestrate the apparently difficult logistics of preparation, transport and processing of their livestock.

4. A case study of case ewes held off pasture

4.1. INTRODUCTION

Mammals presumably evolved homeostatic mechanisms to respond to changes in energy balance in uncertain ecological environments, enabling them to adapt to fluctuating seasonal and shorter-term food availability (Chilliard et al. 1998; Stubbs and Tolkamp 2006; Clauss et al. 2010). Ruminants may be especially well adapted with a fore-stomach continuing to provide dietary energy after feeding has ceased. Another adaptive mechanism is the physiological and psychological state of hunger which normally results in the initiation of feeding. Feed deprivation and hunger is the inevitable outcome of mustering, yarding, handling and transport associated with slaughter. Feed deprivation is also a method of minimising the impacts of effluent accumulation during transport and on carcass contamination. Not surprisingly the animal welfare implications of feed deprivation are also complex (e.g. Hogan et al. 2007; D'Eath et al. 2009; Kasanen et al. 2010) especially given different interpretations of animal welfare (e.g. Duncan and Fraser 1997; Fisher 2009). The needs of animals have to be balanced with the diverse interests of humans, the latter ranging from livestock preparation, procurement, transport and effluent disposal, to concern for the well-being of animals, as well as food safety and product quality.

While many aspects of feed deprivation in sheep have been described, they focus mainly on liveweight loss whilst in lairage and the subsequent effects on carcass quality (e.g. weight and meat tenderness). Most often, fasting was imposed after considerable disruption to animal routines associated with removal from feed, handling and transportation. Furthermore, many of the studies involved animals in prime condition. In contrast, less valuable or cull animals, those on limited nutrition (Slee and Halliday 1968; Hogan et al. 2007) or with poor body reserves, may be more susceptible to feed deprivation. This is especially so if feed is limiting and more likely to be allocated to other more valuable stock e.g. lambs, steers and bulls.

The objective of this study was to assess the implications for cull ewes at slaughter when removed from pasture for different periods prior to transport. The approach was to impose a rigorous design upon a commercial practice – the stock were culled, transported and killed in keeping with commercial practices but were removed from pasture for 0, 9, 18 and 30 hours prior to transport. While there are no maximum periods sheep may be deprived of feed (they must receive sufficient quantities for good health, physiological requirements and the minimisation of metabolic and nutritional disorders Anonymous 2010a). The maximum time they may be held in lairage without feed is 36 hours (Anonymous 2010b).

4.2. MATERIALS AND METHODS

4.2.1 Animals

Commercially farmed 3- and 4-year old ewes on a coastal hill country sheep and beef cattle property (Te Apiti Station, Hawke's Bay) were used. Ewes were identified and culled at docking on the basis of failing to raise a lamb during the 2010 season. One week prior to treatment they were weighed (mean 53.5 ± SD 6.87 kg) and their body condition score recorded (2.6 ± 1.10 on a scale of 0-5) – see Table 2. In addition, a pre-trial blood sample was taken by jugular venepuncture from 60 animals. To reduce the potential confounding impacts of handling and of time off pasture on metabolite concentrations, sampled ewes were those first through the yards. All had been mustered earlier and then held in a pasture holding paddock for approximately 4 hours until being quietly yarded (without dogs) for weighing and sampling. Animals had been shorn 3 months earlier, and had been dagged a week prior to blood sampling to remove the necessity of additional handling immediately prior to transport.

4.2.2 Treatments

A total of 240 ewes were allocated to one of four groups (n = 60 in each group) to be removed from pasture for 0, 9, 18 or 30 hours prior to transport. After weighing and individual ear tagging, ewes were kept together on green pasture for one week until separated into groups and returned to subdivided areas of the same pasture (approximately 1500 kg/dry matter per hectare). Nine animals (2 or 3 per group) were considered unfit for transport due to lameness or poor body condition and were removed. Over the subsequent two days, groups were removed from pasture at 3 am, 3 pm and midnight on 10 November, and at 9 am on 11 November and held in yards.

All ewes were loaded in their groups onto a single commercial road transport vehicle (Bushetts Transport, Waipukurau) and transported 65 km (1 hour) to a commercial meat processing facility (Silver Fern Farms, Takapau). To minimise the effect of effluent contamination, ewes off pasture for 30 and 18 hours were loaded on the upper deck of the trailer and truck respectively, those more likely to defecate or urinate transported on the lower deck of the trailer (9 hours) and truck (0 hours). On arrival the ewes were unloaded, briefly showered and swim-washed once then held in their groups until slaughter 2.75 – 3.5 hours after arrival at the plant (approximately 4 hours after removal of the last group from pasture). The work was approved by the AgResearch Grasslands Animal Ethics Committee (Project 12068).

Table 1. Mean (± SD) live weights and body condition scores of cull ewes prior to feed deprivation, and their carcass weights and dressing out percentages (calculated using cold carcass weights) after 0, 9, 18 and 30 hours fasting followed by transport, time in lairage, and slaughter.

	Time (hours) off pasture prior to transport				Effect of time off pasture
	0	9	18	30	
Prior to treatment					
Live weight (kg)	54.58 ± 5.65	52.84 ± 6.68	52.84 ± 6.50	55.11 ± 7.35	-
Condition score (0-5)	2.63 ± 1.01	2.56 ±1.09	2.62 ± 0.99	2.86 ± 1.15	-
After slaughter					
Hot carcass weight (kg)	23.22 ± 3.61	22.39 ± 3.69	22.13 ± 4.01	23.13 ± 4.55	NS
Dressing out %	41.39 ± 4.83	41.13 ± 3.41	40.59 ± 3.36	40.56 ± 3.92	NS

4.2.3 Measurements

Behaviour of the ewes during unloading, and in lairage after washing, was recorded on a hand-held video camera (Sony Handycam) from immediately outside the raceway of each pen. Recording included periods when the yards were relatively quiet (lunch break) and when there was routine yard activity. Segments of 6 periods of each group recorded over a 90 minute period were collated into a 2 minute clip, in nearly all cases of the whole group. The few instances where a group reacted to an external disturbance, or when the presence of stockmen would detract viewers, were not included. A qualitative assessment of the behaviour of the ewes was then undertaken by a number of individuals with 2-5 decades of experience with sheep farming. This ‘free choice profiling’ technique (see Wemelsfelder 2007; Wemelsfelder and Farish 2004; Wemelsfelder et al 1997, 2001) required observers of each of the 2-minute clips to rate each group’s body language on a visual analogue scale from least to most relaxed, frightened, inquisitive, agitated, tired/exhausted, dull/disorientated, confident, anxious/nervous, bright/alert, indifferent, active/vigorous, bored, miserable, uncomfortable, tense, content, poor/ill-thriven, and distressed. The descriptors were largely derived from a protocol developed for the welfare inspection of extensively farmed sheep in the United Kingdom (F. Wemelsfelder, unpublished data).

Blood samples were collected at exsanguination, stored on ice and serum removed following centrifugation and frozen until required for analysis. Serum could not be recovered from 0, 3, 4, and 6 samples from the 0, 9, 18 and 30 hour groups respectively. Samples were analysed for glucose, free fatty acids, β-hydroxybutyrate, triglycerides, and urea by a commercial veterinary diagnostics laboratory (Gribbles Veterinary, Palmerston North).

Bacteriological and coliform contamination was determined from swabs taken from the neck cut region of 25 carcasses per group 1-1.5 hours after slaughter according to the New Zealand Food Safety Authority (www.nzfsa.govt.nz) National Microbiological Database procedures. Hot and cold carcass weights and dressing out percentages were recorded and 24 hours after slaughter, ultimate pH was measured on the shortloin (longissimus dorsi). Shortloin samples were also cut, allowed to bloom and meat colour measured with a Minolta portable chromameter (model CVR-200b) using the CIE lab numeration system (Rigg 1987). All measurements were analysed by analysis of variance (Payne et al. 2007) and all results, unless otherwise indicated, are expressed as the mean ± SD.

4.3. RESULTS

4.3.1 Behaviour

Unloading of ewes at the processing plant was uneventful. Animals not deprived of feed prior to transport defecated in the laneway leading away from unloading and faeces were also apparent on the floor of the truck where this group was transported. All ewes passed though the washing facilities routinely, only one animal (18 hours group) was given assistance, albeit slight, to exit the swim-wash. The exception was those not deprived of food prior to transport who appeared more reluctant to enter, traverse and exit the swim-wash than did the other groups. However, these were subtle findings and according to plant yard staff they were well within the norm.

Following the swim-wash, ewes generally stood quietly in lairage (Figure 4) apart from shaking off water, although the 30 hour group generally appeared slightly less active than the other groups. The mean qualitative assessment profiles revealed that all ewes were mostly bored and relaxed and least poor or ill-thriven and miserable (Figure 5). Overall, no obvious patterns were associated with time off pasture were evident although there was considerable variation between respondents (Figure 6).

Figure 4. Ewes in lairage after 30 (top left), 18 (top right), 9 (lower left) and 0 (lower right) hours off pasture prior to transport and washing.

Figure 5. The mean appearance, according to individuals with several decades of sheep farming experience, of sheep in lairage after being fasted for 0, 9, 18 or 30 hours prior to transport.

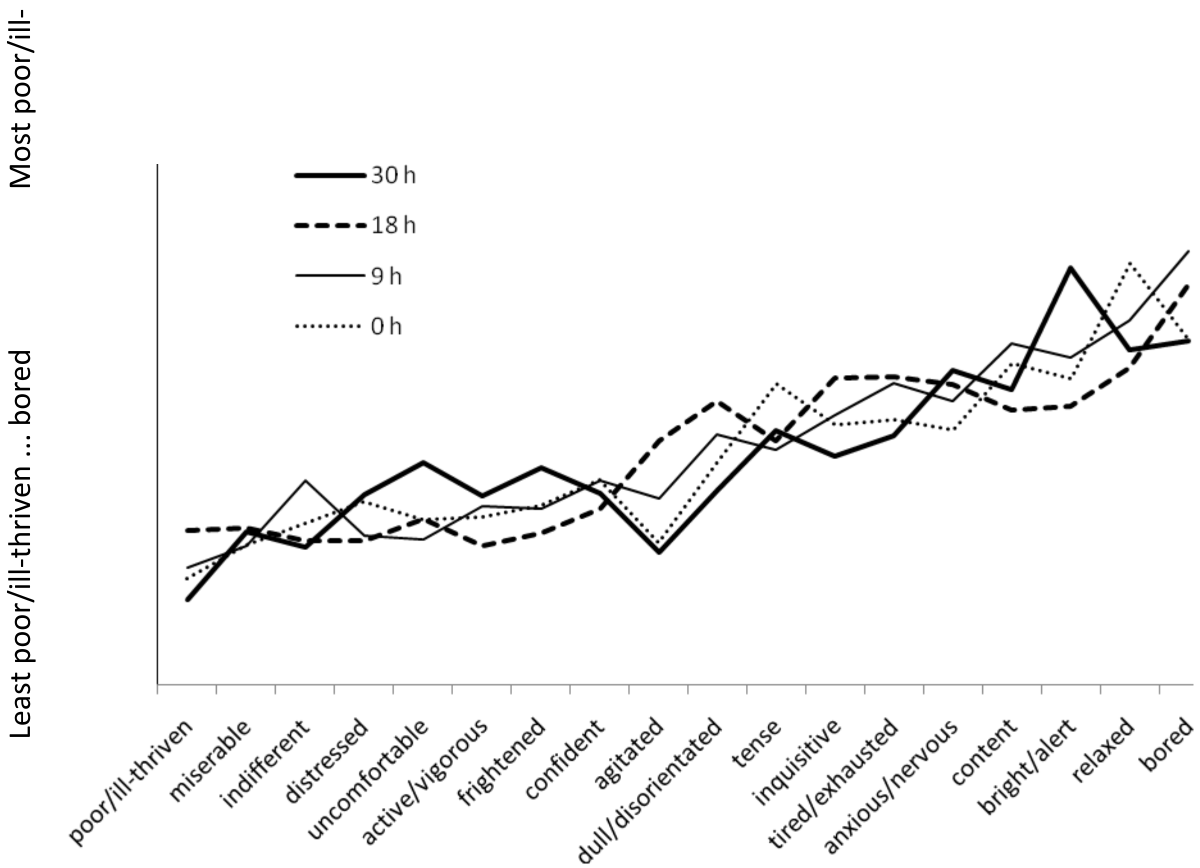
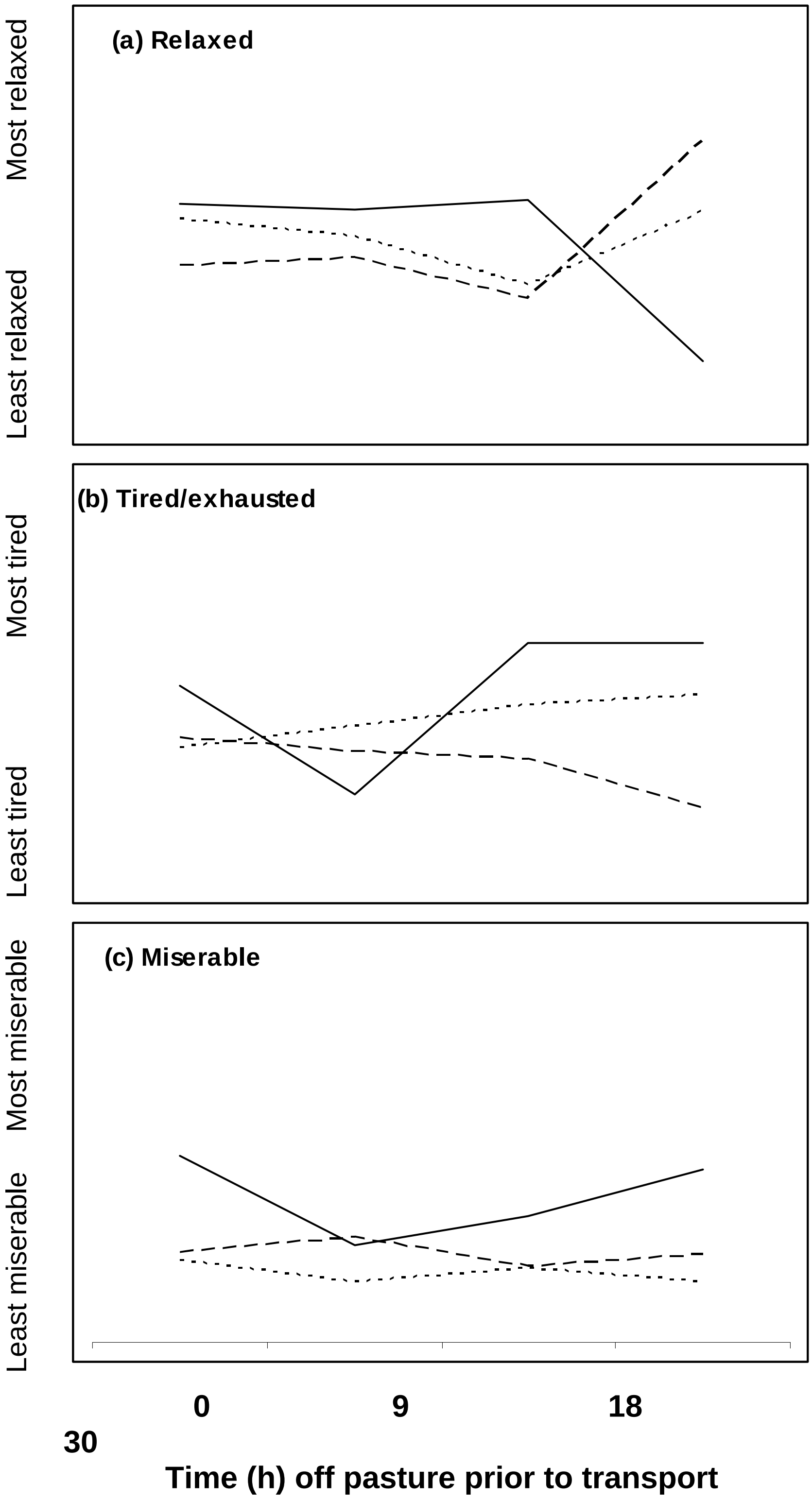


Figure 6. The variation in assessment of qualitative behaviour (relaxed, tired or exhausted, and miserable) from three respondents of ewes in lairage after different periods off pasture prior to transport.



4.3.2 Blood metabolites

Serum metabolite concentrations (mean concentrations are presented in Table 3) were generally higher at slaughter (glucose 0.30-10.10; free fatty acids 0.02-1.63; β-hydroxybutyrate 0.01-1.10 mmoles/l), than at the pre-trial sampling (glucose 3.20-5.20; free fatty acids 0.05-0.80; β-hydroxybutyrate 0.20-0.40 mmoles/l). Triglycerides (0.05-18.4 mmoles/l) and urea (0.40-14.60 mmoles/l) were also higher, but only in the 18 and 30 hour groups, the 0 and 9 hour values similar to those recorded in the pre-trial sample (triglycerides 0.06-0.42; urea 4.80-11.0 mmoles/l serum). Increasing time off pasture prior to transport and slaughter resulted in significant linear elevation (all $P<0.001$) in serum free fatty acids, β-hydroxybutyrate, triglycerides and urea (Table 3).

4.3.3 Carcass attributes

Hot carcass weights (Table 2) ranged from 13.2 – 32.9 kg (mean 22.7 kg). Carcass dressing out % ranged from 27 to 48.6% (mean 40.9%). Different periods of feed deprivation had no significant effect on carcass weights or dressing out percentages (Table 1). Carcass contamination was limited to aerobic microbes (range <1-3200 plate counts) and were >200 plate counts on 8/20 carcasses from ewes fasted for 9 hours prior to transport and slaughter (Table 4). Few carcasses had detectable coliforms. Meat ultimate pH (range 5.28-5.91) was unaffected by the period of feed deprivation (Table 4) but meat became darker (L* 31.51-41.57) and had reduced redness (a* 15.56-24.63) with increasing time off feed.

Table 3. Mean (± SD) serum metabolite concentrations (mmol/l serum) in cull ewes prior to feed deprivation, and after 0, 9, 18 and 30 hours fasting followed by transport, time in lairage, and slaughter. Within rows, values with different superscripts differ significantly.

Metabolite	Pre-experiment	Time (hours) off pasture prior to transport				Effect of time off pasture
		0	9	18	30	
Glucose	3.96 ± 0.38	4.72 ± 1.38	4.85 ± 1.46	5.19 ± 1.41	5.32 ± 1.46	NS
Free fatty acids	0.27 ± 0.16	0.58 ± 0.23^{a}	0.80 ± 0.29^{b}	0.85 ± 0.25^{b}	0.98 ± 0.32^{c}	P<0.001
β-hydroxybutyrate	0.28 ± 0.06	0.42 ± 0.11^{a}	0.47 ± 0.13^{b}	0.49 ± 0.13^{b}	0.69 ± 0.17^{c}	P<0.001
Triglycerides	0.21 ± 0.07	0.22 ± 0.19^{a}	0.22 ± 0.14^{a}	0.30 ± 0.30^{b}	0.29 ± 0.14^{c}	P<0.001
Urea	7.88 ± 1.21	6.94 ± 2.03^{a}	8.28 ± 1.22^{b}	10.11 ± 1.74^{c}	10.17 ± 1.80^{c}	P<0.001

Table 4. Mean (± SD or range) carcass contamination (colony forming units per cm^2) and meat quality attributes (ultimate pH and colour) of cull ewes after 0, 9, 18 and 30 hours fasting followed by transport, time in lairage, and slaughter. Within rows, values with different superscripts differ significantly.

	Time (hours) off pasture prior to transport				Effect of time off pasture
	0	9	18	30	
Carcass bacteriology					
Total aerobic plate count	42.8[a] (<1-164)	407.6[b] (7-3200)	45[a] (1-174)	75.2[a] (1-660)	P<0.001
Escherichia coli	<1	<1-2	<1-2	<1-4	NS
Meat attributes					
pH	5.49 ± 0.09	5.53 ± 0.08	5.53 ± 0.11	5.51 ± 0.11	NS
Colour					
lightness (L)	35.81 ± 1.79[a]	35.79 ± 1.62[a]	35.10 ± 1.80[b]	34.92 ± 1.92[b]	P<0.05
redness (a)	20.81 ± 1.83[a]	20.46 ± 1.51[b]	19.51 ± 1.79[c]	20.26 ± 1.43[b]	P<0.001
yellowness (b)	8.20 ± 1.06[a]	8.08 ± 0.93[a]	7.03 ± 1.36[b]	7.18 ± 1.28[b]	P<0.001

4.4. DISCUSSION

Animals have a complex repertoire of adaptive or homeostatic (physiological and behavioural) mechanisms for dealing with the challenges of constantly changing environments. Sheep can be exposed to feed deprivation during periods of feed scarcity (e.g. winter and during droughts) or to facilitate management practices (e.g. shearing and transport). With increasing feed deprivation sheep progress from using rumen acetate as the main source of energy to drawing on liver glycogen. As this energy store becomes depleted after about 24 hours, fat and subsequently protein (muscle) reserves are mobilised. These changes are normally adaptive and improve the chances of survival. However, if inadequate, excessive, prolonged or maladaptive the responses can result in pathological changes involving suffering, exhaustion and death (Chrousos 1998; Webster 2005).

The responses to 9 hours of feed deprivation prior to transport shown by the ewes in the present study would seem to be within the animals' adaptive capabilities. The sheep appeared relatively normal whilst in lairage and glucose, free fatty acids and β-hydroxybutyrate appeared to be major sources of energy suggesting fat reserves were being mobilised. After 18 hours, triglyceride and urea concentrations were also elevated, indicating further mobilisation of fat reserves and the use of protein (muscle) as a source of energy, a pattern also similar to that after 30 hours off pasture. In addition, the latter group had the highest free fatty acids and β-hydroxybutyrate concentrations, perhaps indicating the fat reserves had become the major source of energy. This group were also perhaps less active in lairage.

These results, and those of Fisher et al. (2010b) indicating up to 48 hours of transport-associated feed withdrawal does not appear to unduly compromise the welfare of adult sheep, suggest that the animals in the present study were adapting to feed deprivation. In contrast, animals exposed to more significant periods of feed deprivation and stress (e.g. Tadich et al. 2009; Alam et al. 2010) show evidence of exhausted body energy reserves or metabolic depletion. Nevertheless, fasted sheep would experience some degree of hunger. Consequently longer periods off feed would need to be increasingly justified since they bring few additional benefits for effluent management during transport - a primary reason for removing livestock from pasture prior to transport. Optimising the period off pasture prior to transport also affects rumen contents and abattoir processing. As fasting progresses, fibre empties from the rumen and replaced by fluid. Whilst the weight change is small, the composition of the rumen contents changes considerably. Large rumen fill makes rumen lifting more onerous, contributes substantially to the amount of water required to clean the paunches and adds to the overall amount of abattoir effluent which could be left at the farm.

While none of the periods off pasture prior to transport affected meat pH, colour was influenced by increasing time off feed. Whilst these effects could be measured with a chromameter, it is unlikely that these differences would be able to be detected by consumers.

It is worth noting that the animals were killed within hours of arrival at the plant i.e. after a short time in lairage. This was to ensure that the effects of time off pasture were not swamped by a further substantial period of food deprivation in lairage. While some abattoirs slaughter stock shortly after arrival by requiring animals to be deprived of food prior to transport, others impose a further period of feed deprivation by accepting stock for slaughter on one day for slaughter the next, principally to ensure they are devoid of effluent and minimising contamination risk and food safety as well as facilitating plant efficiency. While no clear relationship between time off pasture prior to transport and processing and carcass contamination was evident in the present study, 8/20 carcasses from the group removed from pasture for 9 hours, did have higher bacteriological counts (>200). It is difficult to determine if this is a significant finding in terms of time off pasture or whether it merely reflects the inherent difficulties in demonstrating a relationship between on-farm factors and carcass contamination.

There was little to recommend transporting ewes directly off pasture since effluent accumulated during transport and lairage, and they appeared to experience some minor difficulty traversing the swim-wash. This observation may have more relevance to animals with longer fleeces. There is also the possibility that un-fasted animals find transport more difficult. Although motion sickness has been reported in sheep, the circumstances and its prevalence and significance are unknown (see Money 1970), but it has been suggested that effluent contributes to slippery surfaces and difficulties in animals standing during transportation (Fergusson 2006).

The present study has a number of limitations which should be borne in mind. Firstly, the qualitative assessment of behaviour of the animals in lairage may indicate the true state of the animals' well-being. However, the lack of differences may also reflect the stoic nature of some herbivores; that the confined and partly novel environment limited the expression of behaviour; or those assessing the animal behaviour were not familiar in rating behaviour in this way. It would be interesting to let the farmers involved develop their own descriptors of sheep in lairage and then compare the different groups using those descriptors (as the other qualitative assessment studies have done). It would also be interesting to have different individuals, e.g. scientists, complete the behaviour assessments, since farmers may not always be fully aware of the true extent of compromises to animal welfare (e.g. Whay et al. 2003; Dwyer 2009). Similarly, perhaps the inclusion of a group of truly tired or exhausted sheep (see Morag 1967) would provide a valuable reference point. Nevertheless, the rationale for using experienced farmers (they are likely to have been exposed the full range of behaviours) and their overall conclusion that the ewes were not distressed, would suggest that the conclusion that the sheep were largely relaxed but bored is valid. Alternatively, the appearance of the ewes may have been more affected by washing, a recognised stressor (Bray et al. 1989), than by the feed withholding period. Secondly, the times off pasture are likely to be confounded by the diurnal grazing patterns. Sheep (as well as cattle and goats) show a strong preference for grazing legumes in the morning, grass over the course of the day, and bulky feed rich in fibre in the evening presumably reducing the need to graze during the night to avoid predators (Villalba et al. 2010). Consequently, the periods off pasture in the present study may be further influenced by time since the animals last grazed as well as the nature of the herbage consumed. Thirdly, a definitive comparison of blood metabolite levels collected prior to the experiment by jugular venepuncture, with those collected at exsanguination is limited by the influence of those two methods on some metabolites (Warriss et al. 1989).

Finally, this is essentially a case study describing one instance of a line of adult sheep in relatively good condition from a single farm, that were fasted, transported and killed at one time of the year. The sheep farming and processing industries are far from homogenous in New Zealand and elsewhere. Consequently, factors as diverse as class of stock, diet, time of year, climatic conditions, washing, periods in lairage, wool length, and marketing channel (see Knowles et al. 1994; Murray et al. 2000), are expected to affect animal welfare and product quality. Perhaps, if a simple or representative measure of both animal welfare and carcass quality can be determined, an epidemiological-like approach could be developed. The collation of a large amount of data from the industry might then enable the effects and interrelationships of those diverse factors to be understood. In conclusion, and in the absence a more comprehensive undertaking, short periods of feed deprivation prior to transport do not appear to adversely compromise animal welfare.

5. Conclusions

Preparation of livestock for slaughter involves a number of practices designed to facilitate transport, effluent management and hygiene. Industry recommendations require animals to have been removed from pasture for 4-8 hours enabling them to empty out. Most sheep are held in a bare yard or shed or on limited pasture, with water usually available, for 3-12 hours prior to transport for slaughter. This feed deprivation is imposed on the farm principally to reduce the volume of effluent for transport operators, assist with processing and assure product safety.

While livestock preparation, procurement, transporting and processing can be a difficult activity for farmers, transport operators and meat processors to coordinate, it also represents a number of potential stressors for animals. These include mustering, handling, feed deprivation and transport, changes in social and physical environments with the potential to cause fear, discomfort, fatigue, and distress and injury.

Feed deprivation or hunger is one of the more variable stressors, the duration of fasting dependent on factors as diverse as the time of day the sheep are due to be transported to the duration of lairage in different processing plants. It is perhaps the single stressor most easily able to be managed.

The approach taken in this study was that energy metabolism could be separated into 4 phases: feeding, cessation of feeding, fasting and prolonged fasting as indicated by the metabolite measures used. Although some physiological changes may suppress appetite, it was hypothesised that animals would become hungrier and their welfare compromised to some degree as those phases progressed.

The results suggest that sheep in variable body condition were adapting by mobilising fat reserves but without any evidence of metabolic depletion (e.g. depleted blood glucose or high meat pH). With the possible exception of willingness or motivation to feed, hunger is difficult to quantify. Nevertheless, the responses to 9 and 18 hours off feed prior to transport, periods encompassing routine practices, suggest the animals are not experiencing major compromises to their welfare. Even at 30 hours, the animals appeared to be adapting albeit with increased fat mobilisation and were generally less active perhaps indicating fatigue. Consequently, the recommended 4-8 hour periods off pasture prior to transport appear well within the animals' capacity to adapt to fasting. However, the period of feed deprivation also includes transport and lairage and the duration of these additional, and inevitably variable, periods also needs to be borne in mind.

Sheep deprived of pasture for these lengths of time usually resume grazing as soon as they have the opportunity to do so suggesting that they experience some degree of hunger. It would thus seem prudent to avoid unnecessarily extending the period without food prior to transport as long as a suitable period facilitating effluent management and livestock comfort during travel is reached.

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8. Appendices

Appendix 1 – Survey questions

DATE **INTERVIEWERS INITIALS**
Hello my name is (NAME) from Cinta Research Ltd, (optional we farm at.....) we are an agri-research specialist company that surveys only farmers to improve industry products & services. If your farming property is over 100 hectares (unless dairy unit) & you are the person who makes the policy decisions, may I ask you some quick response questions which take around about 11 minutes. Is now a suitable time.

D1. Please tell me your predominant farm type? **CIRCLE ONE CODE ONLY**		**Circle One**
	Sheep	1
	Beef	2
	Sheep & Beef	3
	Dairy	4
	Deer	5
	Cropping	6
	Other ← Write in	7

ONLY SHEEP OR SHEEP & BEEF FARMERS
The next set of questions focus on your normal practices around preparing stock for transport by standing them off pasture or crop before they are transported for slaughter. These questions have been commissioned by MAF to inform animal welfare recommendations and ensure that research reflects current practices.

Q1. When you send sheep for slaughter, on average how many hours would you say the stock are usually off green feed including pasture or crops, other than hay, before they are loaded?	**Don't Read Out & Circle One**	**Circle One**
	Zero – we just load directly	1
	1 hour	2
	2 hours	3
	3-6 hours	4
	7-12 hours	5
	13-24 hours	6
	25-48 hours	7
	Don't Know	8

Q2. For your farming situation, can you please tell me the reasons why you keep the sheep off green feed including pasture or crops, other than hay, for that period of time before loading them?	**Don't Read Out & Circle All Mentions**	**Circle All Mentions**
	The animal welfare of the sheep	1
	Sheep are better suited to load and travel empty	2
	Requirement of meat processor/contractual obligation	3
	Allow sheep to empty out to prevent wool staining during transport	4
	Reduce any impacts of transport on carcass contamination and meat quality at slaughter	5
	Reduce the volume of effluent for transport operators	6
	Enable additional husbandry e.g. drafting, weighing, dagging, sorting, checking, tagging etc	7
	Best suits management e.g. best time of day (cool mornings) or time for mustering	8
	Best suits truck arrival time	9
	Don't Know	10
	Other (Please specify)	11

Q3. Can you tell me the yard or paddock environment the sheep are held in whilst off green feed including pasture or crops, other than hay, & what is provided or the sheep have access to during this period before they loaded? (Interviewers: we are wanting them to tell us the environment, if water is available, alternative feed is given therefore probe if not mention)	**Don't Read Out & Circle All Mentions**	**Circle All Mentions**
	In a bare yard or shed with concrete/metal/earth/other solid floor	1
	In a yard or paddock on limited pasture	2
	In a sacrifice paddock or strip	3
	Hay fed out	4
	Concentrate / hard feed / silage is fed out	5
	Water provided	6
	Don't Know	7
	NA as the sheep come directly off green feed & loaded	8
	Other (Please specify)	9
Q4. Please tell me the different situations where you may change your normal protocol and have	**Don't Read Out & Circle All Mentions**	**Circle All Mentions**

the sheep off pasture or crop feed for a longer or shorter period prior to sending for slaughter?	Pasture versus a forage crops e.g. brassica	1
	Different class of stock – late pregnant ewes	2
	Different class of stock – weaned lambs	3
	Adverse weather conditions at time of loading e.g. muddy yards	4
	Sheep carrying dust	5
	Processor contractual requirements	6
	Don't Know	7
	Other (Please specify)	8

Q5. Now if the sheep are going other destinations for example the sale yards or another farm – on average how many hours would you say the stock are off pasture or crop before they are loaded?	**Don't Read Out & Circle One**	**Circle One**
	Zero – we just load directly	1
	1 hour	2
	2 hours	3
	3-6 hours	4
	7-12 hours	5
	13-24 hours	6
	25-48 hours	7
	Don't Know	8

DEMOGRAPHICS:

The last questions are about you – so we can analyse the data.

D2.GENDER **Don't read out**	**Circle One**	Male	1
		Female	2
D3. To what age group do you belong?			**Circle One**
	20 - 30 years		1
	31 - 40		2
	41 - 50		3
	Over 50 years		4
	Undisclosed		5
D4. Which of the following effective farm areas by hectare would you fall into? (If given in acres divide by 2.47 to get hectares)			**Circle One**
	0-80 hectares		1
	81-150 hectares		2
	151-250 hectares		3
	251-400 hectares		4
	401-800 hectares		5
	801+ hectares		6
	Don't know / undisclosed		7
D5. Which of the following gross farm income groups would you fall into?			**Circle One**
	$Less than 200k		1
	$200 – 500k		2
	$500k +		3
	Undisclosed/Don't Know		4

D6. Area: **Don't read Out**	**Circle One**			
	Northland/ Auckland	1	Wairarapa/Wellington	8
	Waikato	2	West Coast/Tasman	9
	Bay of Plenty	3	Nelson/Marlborough	10
	Gisborne	4	Canterbury	11
	Hawkes Bay	5	Otago	12
	Taranaki	6	Southland	13
	Manawatu /Wanganui	7		

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