final report

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Investigating feed and water curfews for the transport of livestock within Australia - A literature review

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Abstract

This project undertook to (i) review the world literature on curfews (feed and water) as they apply to the land and sea transport of ruminant livestock within Australia (ii) recommend suitable curfew times based on the scientific literature (iii) recommend further research to optimise curfew recommendations.

The overall aim was to make recommendations on curfew regulations and practices that are based on science and the best available information. These recommendations would subsequently be used to determine industry best practice with the aim to optimise animal health and welfare, food safety, meat quality, carcase shrinkage and commercial returns to slaughter and live export supply chains.

Curfew was defined as the time period ‘on farm’ where animals are deprived of feed and/or water before transport. Total time of feed and/or water is the cumulative time that may involve mustering, ‘on farm’ curfew, transportation, sale yards and abattoir lairage.

For slaughter pathways it was recommended that the feed curfew period should be 24 hours or less since the vast majority of faeces has been expelled. The maximum time off feed is recommended at 48 hours to comply with food safety, meat quality and welfare recommendations. Importantly any period of reduction in total time off feed below 48 hours would deliver very significant gains in carcase weight and lean meat yield. The curfew period should be only enough to allow sufficient faecal expulsion to maintain ‘clean’ livestock after transport. Based on industry practice in selected supply chains, it is likely that this curfew period might be typically less than 24 hours.

The manipulation of urine output by imposing water as well as feed based curfews has not been well studied. However the conclusion of the review team was that water curfews would be (i) most likely ineffective in reducing urine loss, (ii) play a minor role as a determinant of clean livestock after transportation and (iii) if imposed, would often mean the farm to slaughter pathway would not comply with maximum time off water requirements as set out by the National Model Codes of Practice.

For live export, the conclusion was that provided animals at registered premises have access to reasonable quality diets for about 5-7 days before embarkation to allow recovery, they can tolerate feed and water deprivation associated with mustering, pre-transport curfew and transport of up to 48 hours and 32 hours in cattle and sheep/goats respectively, without long term impacts on appetite and weight stasis.

The review documented a number of research areas that would help further refinement of curfew practices in Australia.

Executive summary

Slaughter Curfews

Food Safety

The reviewers agreed that food safety was a crucial factor that would drive the final on farm curfew conclusions and indeed total time off feed/water recommendations.

Food safety has both specific issues such selected pathogens like *E. coli* O157:H7 and *Salmonella* spp. and more general issues which are under pinned by carcase hygiene indicator organisms (i.e. *E. coli* biotype 1). Different markets have different requirements with respect to these issues.

Off-feed and water curfew is practiced on-farm to reduce soiling during transport and optimise hide/fleece cleanliness at slaughter. However in microbial terms it represents only one component of pre-slaughter management that influences microbial status of livestock and their subsequent influence on carcase contamination.

The food safety team concluded that to minimise transmission of pathogens and microbial contaminants during carcase dressing, emphasis should be on clean hides/pelts in livestock presented for slaughter. This will minimise direct contamination to the carcase from hide/pelt filth, and in doing so, reduce potential contamination from faeces containing high levels of hazards resulting from long periods off-feed.

While off-feed curfew reduces the potential for faecal contamination of hides/pelts, the additive effect of increasing time-off-feed (including on-farm curfew) on unwanted microbial growth within the intestines produces a countervailing effect. This clearly applies for both *Salmonella* and generic *E. coli*.

Off-feed curfews prior to transport of up to 24 hours are indicated to minimise soiling of the hide/pelt, which is associated with efficient dressing and lower carcase microbial counts. The total time off feed between the farm – slaughter interval is recommended not to exceed 48 hours due to its effect on unwanted microbial growth within the intestines.

The precise length of the curfew to maintain ‘clean’ stock is a complex equation determined by feed type (affecting soft versus hard faeces), coat/wool length and transport time. There is insufficient scientific data on the proportional contribution of these factors to resolve these issues. However Industry practice in commercial sheep supply chains (in Western Australia) suggest relatively short curfew periods are acceptable to allow carcase hygiene standards to be met (see overall conclusions and Table 2 below).

It is suggested that a “cleanliness” or outcomes-based standard should be supported by the implementation of a hide/pelt scoring system that could be related to the economics of dirty hides/pelts (dressing and microbiological) including feedback of scores and financial penalties to producers. A validated scoring system would then allow companies to undertake research with their clients to optimise the curfew periods rather than relying on conservative ‘blanket’ recommendations.

It cannot be assumed that pre-slaughter controls for generic *E. coli* and *Salmonella* will be effective for *E coli* O157/STEC from either grass or lot-fed production systems. The effect of pre-slaughter controls for sheep carcase hygiene is similarly unreliable. Therefore, greater focus should be on optimal dressing procedures to minimise hazards and the attainment of excellent microbiological status of carcases.

These should receive greater emphasis than pursuing complex pre-slaughter controls that are subject to considerable variation in microbial efficacy, and as such, are unsuitable as Critical Control Points within a HACCP system.

Environmental and Biosecurity

From an environmental perspective, a 24 hour curfew (off-feed) would appear to significantly reduce the manure load released by cattle during transit. Urine load was not considered as a major environmental issue. Reductions of 50% or more in effluent production compared to fully fed controls have been reported in studies of cattle fasted for 24 hours. There are commensurate reductions in excretion of organic and nutrient contaminants, all of which pose environmental risks if spillage occurs in transit, especially in populated areas. There is only marginal additional benefit for longer curfew periods and clearly a need to investigate the efficacy of shorter periods especially given the industry practices in Western Australia cited below. The review also highlighted the limited data available for sheep and lambs.

It was concluded that a curfew of less than 48 hours would have little, if any, mitigating impact on biosecurity risks associated with weed dispersal and disease spread. This essentially implies that curfew plays no role in biosecurity.

Meat quality and carcase yield

The issue of meat quality is largely driven by the need for adequate levels of muscle glycogen at slaughter. Muscle glycogen levels are secured by ensuring good nutrition on farm in the 2 weeks leading up to consignment to enable minimum recommended growth rates (0.8-1kg/day for cattle, 100gm/d for cross bred lambs and 150gm/day for Merino lambs). In addition stress should be minimised during the mustering, curfew and post farm gate segments of the pre-slaughter period. In this sense ‘total time off feed’ is considered the major risk factor rather than the curfew component. Thus muscle glycogen will either stay constant or decline but never increase during the immediate farm to slaughter period. Therefore the curfew period alone is not the issue but more the total time off feed and water. The recommendations are that total time off feed for slaughter cattle and sheep should be no more than 36 and 48 hours respectively and that lairage can be quite short (4 hours) if needed. There is evidence that particularly cross bred lambs are more resilient with respect to glycogen metabolism than yearling cattle. The issue with respect to curfew time is that it can represent a significant component of total time off feed.

Carcase weight losses are associated with food and water deprivation. The carcase weight losses begin to occur after 24 and 12 hours off feed in cattle and sheep respectively. The losses are in the order of 0.1% and 0.04% per hour out to 48 hours for lambs and cattle respectively. Water deprivation alone can reduce carcase weight by 3% and lean meat yield by 4% in lambs. Clearly strategies that allow the time off feed to be reduced or hydration status to be increased will allow more carcase weight and lean meat yield. For example reducing time off feed in slaughter lambs from 48 to 36 hours equates to about 0.24kg of extra carcase weight.

Welfare

This review dealt with the direct effects of food and water deprivation on animal welfare and concluded that based on physiological and metabolic indicators, fasting for 24-48 hours resulted in small but acceptable changes in healthy dry livestock.

Dehydration was cited as the most significant animal welfare concern.

It was concluded that the National Model Codes of Practice for the Land Transportation of Livestock (NMCOP) are appropriate on animal welfare grounds with respect to water deprivation recommendations (36 hours for cattle greater than 6 months of age, 36 hour for sheep greater than 6 months of age and 20 hours for lambs less than 6 months of age with some margin for some extension during very long transport).

Based on typical Industry farm to slaughter pathways the length of the curfew period would break NMCOP recommendations only if water was not made available. However the NMCOP recommendations are unclear with regards to recommendations for total time off feed.

There was insufficient scientific evidence to conclude that pre-transport curfew improves the capacity of ruminants to cope with transport.

It was recommended that there would be value in developing strategies to improve the capacity/willingness of animals to consume water when it was available during lairage and in saleyards.

Overall conclusions

A summary of the different recommendations from each discipline segment is shown in Table 1. The recommendation clearly shows that the curfew period should be 24 hours or less since the vast majority of faeces has been expelled. The maximum time off feed is recommended at typically around 48 hours to comply with food safety, meat quality and welfare recommendations. Importantly any period of reduction in total time off feed below 48 hours would deliver very significant gains in carcase weight and lean meat yield. Accordingly the curfew period should be only enough to allow sufficient faecal expulsion to maintain ‘clean’ livestock after transport. It is likely that this curfew period might be typically less than 24 hours (Table 2).

The manipulation of urine output by imposing water as well as feed based curfews has not been studied scientifically. However the conclusion of the review team was that water curfews would be (i) most likely ineffective in reducing urine loss, (ii) play a minor role as a determinant of clean livestock after transportation and (iii) if imposed, would often mean the farm to slaughter pathway would not comply with NMCOP dehydration standards.

Table 1. The recommended time period (hours) off feed or water to maximise each of the discipline segments in livestock destined for slaughter.

Discipline Segment	Feed Curfew	Total time off feed	Water recommendation when not in transport	Total time off water
Food safety	≤ 24 (enough to ensure clean hides/pelts)	≤ 48 (minimise pathogen over growth)	Available	NA[a]
Environmental	≤ 24 (minimise faecal production)	NA	Available	NA
Biosecurity	≥ 48-72 (minimise seed loss in faeces)	NA	Available	NA
Meat quality	NA	cattle ≤ 36 sheep ≤ 48 (minimise dark cutting)	Available	Manage hydration index (urine specific gravity)
Carcase loss	NA	cattle ≤ 24 sheep ≤ 12 (carcase shrink after this time)	Available	Manage hydration index (urine specific gravity)
Welfare	Unknown (effects on transport stress not known)	cattle ≤ 48 sheep ≤ 48	Available	adult cattle ≤ 36[b] adult sheep ≤ 36 young sheep ≤ 20

[a]NA – no recommendation since not relevant

[b]Adult cattle or sheep defined as dry and > 6 months of age. Young sheep defined as lamb < 6 months of age. Recommendations same as NMCOP including special cases for extension.

Evidence that the curfew period can be reduced below the maximum recommended time of 24 hours can be found in industry. For example the Q-lamb alliance regulations on curfew for slaughter lambs (Table 2) recommend relatively short curfews of between 6-12 hours depending on feed type and transport duration.

Table 2. Q-lamb curfew recommendations

Feed type	Transport duration (hours)	Pre-transport curfew recommendation (hours off feed only)
Spring pasture (= suckers mainly)	Short (<4)	6
Spring pasture (= suckers mainly)	Long (>4)	8-12
Dry feed, grain assisted or feedlot (= weaned lambs)	Short (<4)	4-6
Dry feed, grain assisted or feedlot (= weaned lambs)	Long (>4)	8

Another Western Australian lamb supply chain, WAMMCO International, has similar recommendations of between 8-12 hours feed curfew regardless of distance transported. Both supply chains require a feed only curfew with access to water allowed.

Future research – slaughter curfews

Each review has a detailed list of recommended research areas. Below is the consolidated recommendation of the review team for future research:

(i) *(a) The effect of time off feed and water on faecal, urine and E.coli expulsion*

The purpose of this experiment would be to examine in detail the time response of faecal, urine and pathogen expulsion in the 0-24 hour period post fasting. Previous research has not addressed this period.

A suggested experimental design might be:

- 2 species (cattle x sheep)
- 2 levels of hydration (plus/minus water)
- 2 types of feed (lush pasture x dry finishing diet)
- 5 times periods for measurement (0, 6, 12, 18, 24 hours)

Measurements to include numerous faecal and urine parameters. This experiment would best be done using an intensive laboratory design if possible.

(b) Trucking off pasture

There was insufficient scientific evidence to conclude that pre-transport feed curfew improves the capacity of ruminants to cope with transport (i.e. effects on slippage and travel sickness). However it is understood there is currently work being undertaken in cattle to investigate the effects of feed curfew and trucking time in pasture fed cattle. It is recommended that similar work be undertaken is sheep.

A suggested design might be:

- 4 levels of feed curfew (0, 6,12, 24 hours)
- 2 levels of trucking time (5, 15 hours)

However the design would be heavily influenced by the outcomes of experiment (i). Measures to include welfare, dehydration, slippage, pelt score and microbiological data. The aim of experiments described in (i) would be to develop a 'curfew' predictor.

(ii) Economic analysis

An important component in all the research strategies would be an economic analysis. However in addition a general assessment of economic critical control points would be valuable to assess the interacting effects of:

- Market requirement
- Food safety risk
- Carcase shrinkage
- Trucking cost implications
- Abattoir cost implications

(iii) Hide/Pelt scoring system undertaken with Industry

The purpose of this study would be to develop a robust hide/pelt scoring system (for sheep and cattle) which described quantitatively the 'cleanliness' of livestock at slaughter. Such an index would differentiate between recent faecal and older material (i.e. dags). Statistical advice from the food safety researchers would be needed to determine and design the scoring system so as it could be underpinned by carcase hygiene measures.

The final outcome of a carcase scoring system would be to aid supply chains to bench mark their partners (producers, saleyards, transports) with respect to curfew, transport and other factors which underpin carcase hygiene. After analysis the supply chains could confidently recommend minimum curfew times appropriate to their situation.

(iv) Improving the hydration of slaughter lambs and sheep with scoping studies in cattle

It was recommended that there would be value in developing strategies to improve the capacity/willingness of lambs and sheep to consume water when it was available during lairage and in saleyards. This study would be closely linked to Industry. It was also recommended to undertake preliminary studies in cattle to examine the occurrence of dehydration (using the techniques delivered in lambs and sheep).

(v) Methods by which faecal consistency could be made firmer in sheep fed lush pasture and cattle fed lush pasture or feedlot diets

Loose faeces were highlighted by the food safety review as one of several risk factors. This is a complex area and could have several facets. There is little published data focused on understanding stool formation and consistency in sheep or cattle. Based on work in monogastric animals particular dietary components are likely to regulate stool consistency and microbial ecology in the gut. One possibly is to undertake some theoretical research to investigate factors affecting faecal consistency and microbiology. The food safety review highlighted some potential positive effects of feeding roughage and indeed some additional affects of specific roughage types. It was recommended that this work would be appropriate in very high risk groups of slaughter livestock – such as lambs consigned from certain lush pastures that induce runny faeces.

(vi) Abattoir hygiene

While out of the scope of this review the food safety conclusions were that new research into abattoir hygiene systems should always be encouraged where appropriate given the complexity of controlling individual food (meat) borne pathogens.

Live export curfew

Overall conclusion

Stresses associated with fasting and transport of ruminant livestock result in disturbances in rumen function, leading to reductions in dry matter intake (DMI) for periods of from 3-14 days with accompanying weight losses which can range from 4-14%. The pattern of weight loss is usually curvilinear, most occurring during the first 12 hours due to gut, urine and body water losses. Better quality diets (adequate energy, protein, roughage, minerals and vitamins) are important for appetite and weight regain to occur quickly after transport to registered premises, and before embarkation of exported livestock. Health problems such as Salmonellosis in sheep and goats, influenced by inappetence, are exacerbated by fasting and transport stresses. The conclusion was that provided animals at registered premises are provided with reasonable quality diets for about 5-7 days before embarkation to allow recovery, they can tolerate feed and water deprivation associated with mustering, pre-transport curfew and transport of up to 48 hours and 32 hours in cattle and sheep/goats respectively, without long term impacts on appetite and weight stasis. Gains in recovery time for shorter fasting periods than 32-48 hours are harder to quantify. However it is suggested that the ‘muster+curfew+transport’ cumulative fasting time would need to be reduced to 5-12 hours if minimal interference to rumen function and live weight loss was the target.

Future research – live export curfews

Transparent recommendations on what are the determinants of a ‘high quality’ diet that registered premises should provide sheep and cattle 5-7 days before embarkation should be agreed upon. This could be undertaken via a workshop between researchers who have undertaken live export nutritional research and Industry practitioners. The recommendations should encompass both northern and southern scenarios.

Contents

1 Project objectives and structure

The aims of this project were to:

- Review the world literature on curfews (feed and water) as they apply to the land transport (road and rail) and sea transport of livestock within Australia.
- Recommend suitable curfew times based on the scientific literature
- Recommend further research to optimise curfew recommendations

This project assembled national experts to write individual reviews on 6 topics applicable particularly to slaughter pathways. An additional review was written with respect to curfews appropriate for sea transport. The reviews were structured a shown below:

1. Undertake literature reviews on the role of curfew time for beef cattle, sheep, lambs and goats with respect to animals destined for slaughter, including the interactions with transport and lairage duration. The review was segmented into the following topics:

I. Food safety and carcase hygiene
II. Biosecurity and environmental
III. Meat quality – Beef cattle
IV. Sheep meat quality
V. Animal health and welfare
VI. Comparing recommendations regarding curfews contained in the regulations, codes of practice with current best practice.

2. Undertake a literature review on the role of curfew time for beef cattle, sheep, lambs and goats with respect to animals destined for sea transport from Australian ports. This review focused on curfew plus transport time (total time off feed & water) and its effect on subsequent ability of animals to regain feed intake, live weight, rumen function and animal health.

3. Overall synthesis of the review chapters to recommend feed and water curfew duration and additional research to further optimise curfew times.

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1.1 Abbreviations & Definitions

CURFEW: was defined as the time period 'on farm' where animals are deprived of feed and/or water before transport.

DRY SHEEP OR COW: implies non pregnant and non lactating

EHEC: Enterohaemorrhagic *E.coli*

HACCP: Hazards analysis critical control points

IMS: Immunomagnetic Separation

LAIRAGE: Enclosures for the purpose of holding livestock temporarily at an abattoir prior to slaughter

MPN: Most Probable Number

NMCOP: National Model Codes of Practice

PFGE: Pulse Field Gel Electrophorsis

REGISTERED PREMISES: are those premises used for holding and assembling of animals for export, or the pre-export quarantine or isolation of livestock for export. They must be located not more than 8h journey time from the port of embarkation. Specifications on livestock handling facilities and sheds, drainage, environmental protection, fencing and isolation requirements are outlined together with minimum standards for management of livestock.

SALEYARD: A cental enclosure to which livestock are transported for the purpose of display and sale by auction.

STEC: Shiga toxigenic *E. coli*

TOTAL TIME OF FEED AND/OR WATER: is the cumulative time that may involve mustering, 'on farm' curfew, transportation, sale yards and abattoir lairage.

2 Review of Food Safety and Carcase Hygiene.

2.1 Authors: Andrew Pointon, Andreas Kiermeier and Narelle Fegan

Abstract

This report provides a literature review on the role of curfew time for beef cattle, sheep, lambs and goats with respect to animals destined for slaughter in relation to meat safety and carcase hygiene. As on-farm curfew is only one component of pre-slaughter events that may influence food safety, interactions with transport, lairage duration and other contributing factors are also considered.
This report is part of a broader review of the impact of curfew on meat quality, animal health and welfare, biosecurity and environmental impacts. The project aims to provide industry with curfew regulations and practices that are based on science and the best available information to determine industry best practice, which will in turn optimise animal health and welfare, food safety, meat quality and commercial returns.

Stakeholders that will benefit from the project include producers (avoidance of penalties from dirty stock), livestock transporters (reduced cleaning costs), processors (more efficient carcase dressing, improved meat quality) and meat exporters (compliance with port-of-entry microbial testing requirements).

This food safety report provides the opportunity to consider pre-slaughter interventions as part of a whole-of-chain approach to comply with increasing microbial stringency of export markets.

Executive summary

This report provides a literature review on the role of curfew time for beef cattle, sheep, lambs and goats with respect to animals destined for slaughter in relation to meat safety and carcase hygiene. As on-farm curfew is only one component of pre-slaughter events that may influence food safety, interactions with transport and lairage duration are also considered.

In recent years the USDA/FSIS has declared *E. coli* O157:H7 an adulterant in ground beef. Beef processors have been required to review HACCP plans to ensure Critical Control Points for *E. coli* O157. This has led to new data on the ecology of *E. coli* O157 to reduce the level of microbial hazards entering slaughter plants, which is at variance with data on other hazards. The review takes into account specific contributing factors for STEC/EHEC especially *E. coli* O157, *Salmonella* spp., and the microbial indicators of carcase dressing hygiene.

While off-feed “curfew” is practiced on-farm to reduce soiling during transport and optimise hide/fleece cleanliness at slaughter, in microbial terms it represents only one component of pre-slaughter management of livestock that influences microbial status. The scope of this food safety and carcase hygiene review, therefore, covers mustering to shackling at the abattoir, to enable the likely impact of “curfew” and other contributing factors to be considered jointly.

In summary, the review indicates the incompleteness of current understandings about the proportional contributions of different pre-slaughter pathways of contamination and the best point(s) where interventions deliver a meaningful reduction in risk. In general, knowledge about microbial hazards is currently far too incomplete to devise on-farm interventions that would be practical and deliver a meaningful reduction in risk. However, without specific interventions that effectively target major hazards (eg vaccines for EHEC) there is still a need to rely on generic controls.

There is no single epidemiology for food borne hazards and carcase contaminants in livestock from farm-to-slaughter. Within stock type/pathway-to-slaughter scenarios the contributing factors to build-up of “microbial populations of concern” vary. This variation also extends between these scenarios. Consequently, with this limited knowledge of the variability of microbial loads and the unknown proportional impact of various contributing factors, only broad control options may be proposed.

While off-feed curfew reduces the potential for faecal contamination of hides/pelts, the additive effect of increasing time-off-feed (including on-farm curfew) on unwanted microbial growth produces a countervailing effect. This applies for both *Salmonella* and generic *E. coli*.

For *E. coli* O157 in cattle (and more so in sheep) the pre-slaughter epidemiology is less well understood. Evidence supports the occurrence of “supershedders” in cattle that may result in high numbers and high potential for within-lot contamination of both livestock and carcases. Counts alone this may over-ride other contributing factors. In view of export market access specifications, intervention(s) for this contributing factor is of paramount importance to exporters of boxed beef trim (22% of carcase weight).

Hence, for minimal transmission of pathogens and microbial contaminants during carcase dressing, emphasis should be on clean hides/pelts in livestock presented for slaughter. This will minimise direct contamination to the carcase from hide/pelt filth, and in doing so, reduce potential contamination from faeces containing high levels of hazards resulting from long periods off-feed.

This “cleanliness” or outcomes-based standard should be supported by the implementation of a hide/pelt scoring system that could be related to the economics of dirty hides/pelts (dressing and microbiological) including feedback of scores and financial penalties to producers. A caveat would be the need to adopt solid floors in transports to eliminate confounding results.

A Pre-slaughter Assessment Tool (PAT) was developed to provide a convenient way of defining the combination of “active” contributing factors for each stock type/pathway-to-slaughter scenario. PAT software scores represent the sum of relevant factors that increase and decrease microbial hazard build-up for each scenario. However, the relative impact on eventual carcase contamination of individual factors, and combination of factors for each scenario, cannot be inferred from these data. Nevertheless, industry stakeholders are provided with an overview of combinations of contributing factors to guide selection of the most appropriate control procedure(s) for each scenario.

Off-feed curfews prior to transport of up to 24 hours are indicated to minimise soiling of the hide/pelt, which is associated with efficient dressing and lower carcase microbial counts. When taking account of times associated with transport, potential saleyards and lairage at the abattoir, this pre-transport “cleanout” may also counter further contamination associated with increased microbial counts within livestock lots subjected to extended time-off-feed. This effect, though, may be less with stock with runny faeces.

Alternatively, as shown for cattle, feeding of specific hay varieties and forms for 48 hours prior to transport leads to reduced counts and firmer faeces with less soiling. Consequently, R&D should include evaluating feeding strategies to replace fasting for some stock type/pathway-to-slaughter scenarios (especially where runny faeces are a common problem).

Fasting and feeding effects for lot-fed cattle are less proven and require further evaluation, particularly in relation to the proportional contribution of sources of contamination (i.e. hide tag score versus changes in faecal shedding as a result of shipment/lairage effects).

It cannot be assumed that pre-slaughter controls for generic *E. coli* and *Salmonella* will be effective for *E coli* O157/STEC from either grass or lot-fed production systems. The effect of pre-slaughter controls for sheep carcase hygiene is similarly unreliable. Therefore, greater focus should be on optimal dressing procedures to minimise hazards and the attainment of excellent microbiological status of carcases. These should receive greater emphasis than pursuing complex pre-slaughter controls that are subject to considerable variation in microbial efficacy, and as such, are unsuitable as Critical Control Points within a HACCP system.

- Consequently, it is recommended to set a Performance Standard of minimal hide/fleece contamination, and let industry utilise the most effective and practical means for each scenario to achieve this outcome. Accordingly, research priorities include:
- Targeted development of pre-slaughter interventions that are risk-based for:
  - lambs and cattle associated with the spring flush (including the type and duration of hay feeding to minimise runny faeces)
  - feeding strategies for long-haul stock (hay feeding and/or not implementing an off-feed curfew for stock coming from fibrous pastures)
  - measures to minimise supershedders of EHECs (*E. coli* O157).
- A cost:benefit analysis of pre-transport feeding, taking into account carcase weight and reduced abattoir costs to minimise carcase contamination risks, versus possible truck cleaning costs is warranted.
- Research on nutritional methods of manipulating the faecal flora of ruminants before slaughter, considering EHEC, *Salmonella* and carcase hygiene outcomes.
- A strategy paper to be prepared on alternative feeds and feed supplements that could be used to reduce the excretion of undesirable bacteria in faeces during the pre-slaughter period. This would include suggestions on which prebiotics, probiotics and synbiotics should be tested, particularly in lot-fed cattle.
- Regional differences in relation to the time-off-feed, type of feed interactions should be investigated to quantify the proportionality of pathways of carcase contamination i.e. hide versus ingesta contributions to carcase contamination in long-haul grass-fed cattle in Nth Australia.
- It is recommended that abattoirs document their management of hide contamination.
- It is recommended that the cattle and sheep slaughter industry implement a recognised system of tag/dag scoring.

2.2 Introduction

The Australian red meat industry is composed of approximately 20 million cattle and 100 million sheep. Australia is the world's largest exporter of beef (23% of total world exports) and the second largest exporter of sheep meats (42% of total world exports). It is also the largest exporter of goat meat. Given its role in the global meat trade, the protection of the public health of consumers domestically and elsewhere is a high priority for the Australian industry that is reflected by its strong commitment to Codex guidelines (FAO/WHO, 1995). Risk assessment has become the tool of choice for a variety of functions, including framing of risk-based regulation and of prioritising research and development to fill data gaps and reduce uncertainties from production to consumption. Risk profiling is one activity in preliminary risk management that has recently been defined as ‘a description of a food safety problem and its context’ (CAC 2003a). The provision of a comprehensive description of the food safety problem associated with the pathogen(s):commodity combination(s) has more recently been advocated (CAC 2003b). This internationally accepted risk-based approach, therefore, provides the appropriate context for this review of pre-slaughter livestock management arrangements.

In recent years considerable new evidence regarding the ecology of food borne pathogens, notably *E. coli* O157, has emerged as a result of USDA/FSIS declaring *E. coli* O157:H7 an adulterant in ground beef. Beef processors have been required to review HACCP plans to ensure Critical Control Points for *E. coli* O157 (Federal Register 1996, 2002; FSIS 2002). From this new data and trials on interventions to reduce the level of microbial hazards entering slaughter plants, it is apparent that the ecology of these hazards is influenced by many contributing factors. It is the interaction of these factors associated with each stock type/pathway-to-slaughter “combination” (i.e. marketing scenario) that ultimately determines the hazard load that each presents upon entry to the abattoir. This review aims to establish the set of contributing factors and their microbial consequences relevant to each scenario to inform a wider re-evaluation of pre-slaughter arrangements. This review draws substantially on a series of hazard:stock type evaluations developed within the risk profile of the Australian red meat industry (MLA 2003a,b; Pointon et al 2006; Sumner et al 2005a,b; Horchner et al 2006).

While off-feed “curfew” is practiced on-farm to reduce soiling during transport and optimise hide/fleece cleanliness at slaughter, in microbial terms it represents only one component of pre-slaughter management of livestock that influences microbial status. The scope of this food safety and carcase hygiene review, therefore, covers mustering to shackling at the abattoir, to enable the likely impact of “curfew” and other contributing factors to be evaluated.

The review takes into account specific contributing factors for EHEC/STEC especially *E. coli* O157, *Salmonella* spp., and the microbial indicators of dressing hygiene. Ultimately, summaries of contributing factors for each hazard:stock type/path-to-slaughter scenario are presented.

Furthermore, the contributing factors are discussed in a manner that enables stakeholders to relate the findings to various outcomes of interest including ease of dressing, visible contamination on carcases, the overall microbial status of carcases and hazard presence/absence.

2.3 Microbial Hazards and Contaminants

2.3.1 Shiga toxigenic Escherichia coli (STEC) – E. coli O157

STEC are a group of *E. coli* that produce Shiga toxin. All STEC produce Shiga toxin but only some are considered to be pathogenic to humans. The most notable group of pathogenic STEC are the Enterohaemorrhagic *E. coli* or EHEC. Several EHEC serotypes have been identified in Australia including O157:H7, O26 and O111.

Ruminants are the primary animal host although EHEC have also been isolated from pigs, dogs, cats, horses and birds. EHEC can survive for months in the environment. With respect to market access, the most important EHEC is *E. coli* O157:H7, which is a meat-borne hazard. In the US and the UK *E. coli* O157:H7 is the dominant serotype associated with disease, while in Australia a range of serotypes have been isolated (Sumner et al 2005a). Most studies have concentrated on *E. coli* O157.

2.3.2 Salmonella spp.

Salmonella spp. are carried in the intestinal tract of most mammals and birds. Although all *Salmonellae* are considered to be capable of causing disease in humans and animals, serovars differ in the pathological syndromes that they produce. Some serotypes are host specific such as *Salmonella* Typhi in humans, *S.* Abortus-ovis in sheep and *S.* Dublin in cattle. Non-host specific serotypes are those of principle zoonotic significance.

Salmonella can survive for long periods in the environment and under certain conditions are able to multiply in the external environment and water.

2.3.3 Indicator Organisms

Much of the microbiological testing of meat is done to verify process control measures in the context of properly implemented HACCP systems to ensure food safety. The incidence and distribution of pathogens on live animals, carcases, primals, ground meat and other meat products is non-random and infrequent. In testing programs, food borne pathogens will not be detected consistently when they are non-randomly distributed and/or occur at a low incidence. Consequently, testing for pathogens directly cannot reliably verify the safety of a process.
Indicator organisms are groups of bacteria that indicate the possible presence of organisms of concern, and may point to the origins of the microbial contamination. The indicator groups are chosen so that assumptions can safely be made that their numbers are higher than the numbers of organisms of concern. Therefore, total aerobic plate counts of viable microorganisms (TVC), or counts of other commonly accepted indicator organisms (e.g. coliforms, *E. coli* biotype 1, or Enterobacteriaceae) could be used to verify proper application of processing procedures, sanitation programs and GMPs.

Generally the presence of indicator organisms on meat constitutes neither a recognised nor a potential public health hazard. However, experience shows that they can be a hazard to trade if the implications of their presence are misinterpreted by customers. Nevertheless, generic *E. coli* biotype 1 is generally accepted to indicate contamination by faecal matter, and as such is of some interest for this review.

2.4 Generic Factors Affecting Microbiological Hazards

In the context of the application of HACCP in the meat industry (Gill 2000), the following, unavoidably simple, principles relate to pre-slaughter management of stock and carcase hygiene (Gill 2004; Gregory in MLA 2003a,b). They apply to the enteric bacteria that are found in livestock and are potentially pathogenic to the public:

1. Enteric pathogens found on meat are mainly associated with faecal matter that is deposited on the carcase during the slaughter process.
2. Such matter will be more prevalent on carcases from animals that are visibly dirty at the time of slaughter than on carcases that are clean.
3. It can be more difficult to eviscerate and dress carcases hygienically when animals have liquid diarrhoea. Diarrhoea is more likely to cause contamination of the body surface, and it can introduce hazards during evisceration.

4. Animals carrying dust, dags or clinker in their coats or fleece are more difficult to dress hygienically than animals with clean hides or pelts. This is a concern with cattle kept in some feedlots.
5. Truck, holding pen and stunning pen walls and floors that are wet and dirty are more likely to cause body surface contamination than walls and floors which are dry and clean. Such body surface contamination could introduce risks of transfer of soiling to the carcase during hide or pelt removal.
6. It can be more difficult to remove the pelt of a sheep or lamb carcase hygienically that is in long wool in comparison with a shorn fleece. The importance of this effect depends on breed, and on the ways in which roll-back of the fleece is controlled at individual abattoirs.

As the process of "Curfew" sits within a pre-slaughter system, factors determining the contamination level of hides at slaughter from mustering to shackling at the abattoir (Figure 1) are reviewed to provide a background against which the impact of on-farm curfew can be evaluated. The contributing factors to both external and internal contamination (Figure 1) are subsequently reviewed to identify the combination of factors for each hazard:stock type/path to market scenarios.

The following sections provide background against which the "microbial" impact of on-farm feed curfew may be evaluated.

2.4.1 Curfew Mechanisms

In summary, there are two mechanisms by which on-farm pre-transport food curfew may impact on food safety and carcase hygiene (Figure 1). The first relates to minimising the direct transfer to the carcase of hide/pelt contamination that arises under production and transport systems. The second concerns the capacity for accelerated growth of some microbial hazards and hygiene contaminants as the time-off-feed increases from mustering-to-slaughter (including feed curfew on-farm). This increased gut content contamination may result in carcase contamination via further hide/pelt faecal contamination during transit to slaughter or by ingesta spillage during carcase dressing procedures.

In the adequately-fed animal, fluid and fine particles might spend on average 7-12 h in the rumen, and larger particles, 12-48 h. Particles trapped between the leaves of the omasum may spend 2 h there. Beyond the omasum there is no physical barrier to digesta passage and the movement of contents is under physiological control. The mean residence time in the abomasum is about 0.5h, and in the small intestine 2.5 h. According to calculations by Hecker and Grovum (1975), the residence time in the large intestine is approximately 19.7 h in sheep and 10.1 h in cattle. This may be the basis for the difference in curfew times recommended for sheep and cattle in the Australian Live Export Standards (Anon, 2001) and conceivably for stock being prepared for slaughter.

2.4.2 Visible Scoring of Hide and Fleece Contamination

The regulatory authorities in a number of countries have instituted regulations designed to prevent the slaughter of excessively dirty cattle and sheep. This is in recognition of the contamination of animals presented for slaughter with excessively dirty hides carrying adherent dirt, faeces and straw. In Finland special hide regulations have been in place since 1982 (Ridell & Korkeala 1993) resulting in substantial reduction in the "incoming problem". The Australian Meat Safety Enhancement Program restricts the slaughter of excessively dirty cattle (MLA 2003a,b).

Systems to quantify the external contamination of cattle (Ridell & Korkeala 1993; Jordan et al 1999; McEvoy et al 2000; Davies et al 2000; Collis et al 2004) and sheep (Hadley et al 1997) have been used to benchmark industry status and link the degree of livestock with carcase contamination. Jordan et al (1999) reported the system to be a reliable industry tool, and Ridell and Korkeala (1993) reported a reduction of 85% in dirty cattle when applied at the industry level.

A pilot survey of tag scores in Australia (Figure 2) suggest that Australian cattle are presented for slaughter in a much higher state of cleanliness than their North American counterparts. Moreover, there appears to be less variation in tag scores in Australian cattle than in the North American industry (MLA 2003c).

Biss and Hathaway (1995) found a 0.7 log count/cm^2 difference for TVC on sheep carcases between dirty woolly washed lambs and clean shorn unwashed lambs immediately after pelting.

2.4.3 Link between Live Animal and Carcase Contamination

The link between hide cleanliness (hide/fleece scores) and bacterial numbers on cattle and sheep carcases has been reported in several studies (Chapman et al 1993; Ridell & Korkeala 1993; Hadley et al 1997; McEvoy et al 2000; Collis et al 2004). In cattle, filth on the hock and brisket was directly related to these areas having the highest levels of carcase contamination with TVC (McEvoy et al 2000) and *E. coli* O157 (Reid et al 2002). This is in agreement with Ridell and Korkeala (1993), who reported that briskets from excessively dungy cattle were significantly more contaminated than briskets from cattle which did not have large amounts of dung on the hide. Bell (1997) states that carcase contamination associated with clean hide contact is significantly lower than that following contact with pre-slaughter washed faecally soiled hide. Bell concludes that *improved carcase hygiene acceptable to New Zealand's various export markets rests more comfortably with attention to stock cleanliness and flaying practice than with strategic interventions such as antimicrobial sprays, carcase irradiation or steam pasteurisation*. Hadley et al (1997) demonstrated a large 2 log difference between carcases from extensively soiled and wet fleeces when compared to those from clean animals.

However, there is also evidence that the means of transmission may be of a more general nature from (dirty) carcases (Biss & Hathaway 1996a). The level of visible contamination of carcases is commonly used as an indicator of the hygienic standard of the slaughter and dressing process in HACCP plans. However, results of trials on visible contaminants on ovine carcases can only be used as an indicator of poor hygienic status of the carcase directly affected by the contamination and not as a measure of the hygienic status of the carcase as a whole. Just as the isolation of *Salmonella* from the carcase is believed to relate more to the presence of the pathogen in the gastrointestinal tract of the live animal than to a breakdown in the slaughter process (Lowry & Bates 1989; Biss & Hathaway 1995, 1996a,b). Biss and Hathaway (1996b) demonstrated that pre-slaughter washing of "woolly" lambs decreased visible contamination on carcases but actually increased the levels of microbial contamination on the carcase.

More recent studies on the correlation of *E. coli* O157 prevalence from faeces, hides and carcases has shown faecal and hide prevalence significantly correlated with carcase contamination indicating a role for control of *E. coli* O157 in live cattle (Elder et al 2000). A companion genotypic analysis study demonstrated that *E. coli* O157 carcase contamination originates from animals within the same lot and not from cross-contamination between lots (Barkocy-Gallagher et al 2001).

Additional supporting evidence in beef plants is the finding of a correlation between the incidence of *E. coli* O157 and TVC counts on hides and that in pre-evisceration samples (Arthur et al 2004). The results of quantitative studies in Australia found counts of generic *E. coli* were not correlated with counts of *E. coli* O157 and *Salmonella* (MLA 2003d, MLA 2005). However, from 4 lots of 25 animals, the most highly *E. coli* O157 contaminated lot prior to slaughter also yielded the only 6 carcases contaminated with *E. coli* O157 (Fegan et al 2005a). This effect was observed in a subsequent study where one animal was shedding 4.6 x 105 MPN/g of *E. coli* O157 in faeces and the carcase of this animal and one other in a group of 30 were contaminated (MLA 2006). Controls aimed at preventing this high shedding of bacteria by some individual cattle is thought to be an effective strategy for reducing the prevalence of *E. coli* O157 in cattle (Matthews et al 2006). The ratio of transmission of TVC and *E. coli* from hide to carcase has been estimated in three studies (Newton et al 1978; Bacon et al 2000; Vanderlinde et al 1996). Nou et al (2003) demonstrated that effective hide decontamination interventions can also significantly reduce carcase contamination with *E. coli* O157.

More recently PFGE analyses of *E. coli* O157 (Avery et al 2004) demonstrated not only a correlation of strains between farms and carcases, but also the isolation of additional identical types from hides, lairage environment, and carcases. This confirms the significance of cross contamination (both pre-slaughter and during skinning) taking place at the abattoir i.e. originally *E. coli* O157-free animals (and resultant carcases) becoming contaminated during the farm-slaughter-dressing chain of events. Aslam et al (2003) provided convincing evidence that ground beef contamination originates from faecal microflora by demonstrating tracking the genetic homology of *E. coli* strains from cattle faeces to product.

Controlling hide cleanliness may not minimise all sources of contamination by pathogens. Sites other than the hides and faeces of cattle may also be sources of pathogens which may contaminate carcases. Oral cavities and saliva have been found to contain *E. coli* O157 and *Salmonella*, with isolation rates often higher than those from faeces (Keen & Elder 2002; Fegan et al 2005a,b). *E. coli* O157 was not found in samples from the rumen of cattle (Fegan et al 2005a) which is consistent with colonisation occurring in the lower intestine (Grauke et al 2002; Naylor et al 2003). *E. coli* O157 has occasionally been isolated from rumen fluid (van Donkersgoed et al 1999), particularly in the first few days after inoculation with *E. coli* O157 (Grauke et al 2002). In contrast *Salmonella* has frequently been isolated from rumen material (Samuel et al 1979; Samuel et al 1980; Samuel et al 1981; Fegan et al 2005b). Numbers of *Salmonella* present in rumen material may be as high as 1.1 x 10^4 MPN/g (Fegan 2005b). This information indicates that the risk of carcase contamination with *E. coli* O157 from a ruptured rumen/paunch is low, while the risk of *Salmonella* contamination is high.

The sources and routes of contamination of cattle carcases with *Salmonella* and *E. coli* O157 are still not clear but evidence from the MLA project PRMS.030 (MLA 2003d) suggests that oral cavities and hides may be important sources, with high numbers of pathogens also playing a role. Contamination of carcases with *Salmonella* and non-toxigenic *E. coli* O157 may not result directly from the faeces, rumen, hide or oral cavity of that particular animal, with other sources, such as adjacent carcases or sites from other animals within a group playing a more important role for contamination. PFGE analysis of non-toxigenic *E. coli* O157 isolates obtained from the hides and oral cavities of cattle were most often indistinguishable from isolates found on carcases, whereas the PFGE types isolated from the rumen and faeces of these animals were generally not found on the carcases. The carcases of these animals may have become contaminated through either direct contact with the hide and/or oral cavity material or from workers or equipment which may have contacted the hide and/or oral cavity and the carcase. Indistinguishable PFGE types of non-toxigenic *E. coli* O157 were often observed on adjacent carcases, indicating that direct contact between carcases or contact with the same contaminated material was involved in contamination of carcases (MLA 2003d). With toxigenic *E. coli* O157 the source of carcase contamination is likely to be the faeces or hides of animals where the counts of this organism are high, with that animal and possibly adjacent animals and their carcases becoming contaminated. Unlike *E. coli* O157, no relationship was observed between the *Salmonella* PFGE types isolated from the carcase of an individual animal and those obtained from other sites on the same animal. Some isolates (2 out of 7) obtained from carcases had the same PFGE type as isolates obtained from different animals within the same group. Other *Salmonella* isolates may have been present in the samples but were not isolated in the study or carcase contamination with *Salmonella* may come from sources other than the animals from which the carcases were derived, such as the abattoir environment or workers. However, there were only a small number of positive samples for comparison in this study limiting the significance of these results (MLA 2003d). Consideration must be given to the different ecologies of different pathogens when designing intervention strategies to ensure the control of one pathogen does not lead to the proliferation of another.

The more recent studies support earlier opinions and remove uncertainty with regard to the significance of hide/pelt contamination as the principal source of carcase contamination. As summarised in the final report for MLA project (MLA 2003c), which included a literature review on the hide cleanliness of cattle; "*The overwhelming opinion in the scientific literature is that hide cleanliness is a moderate to strong determinant of carcase hygiene. However, some of this viewpoint is based on theoretical arguments and although these arguments appear to have been well accepted there is a lack of studies that unequivocally demonstrate their correctness. Of the studies performed in cattle none provide unequivocal evidence of the strength of relationship between tag and carcase hygiene. However, most studies demonstrate a trend for carcase hygiene to be moderately or strongly associated with hide contamination. Although there are flaws in the design and execution of these studies their tendency to collectively agree on the direction and magnitude of the relationship is notable. One study performed in Canada (van Donkersgoed et al 1999) reported no association between hide contamination and carcase hygiene. However, there are also reasons to doubt the validity of these findings (some are acknowledged by the authors).*"

2.4.4 Production Factors Affecting Carcase Hygiene

In cattle in the UK, Davies et al (2000) found feed type, coat length, journey distance and time were the principal factors that affected the dirtiness scores. For sheep, Hadley et al (1997) showed that increased fleece length was associated with increased soiling of live animals. Biss and Hathaway (1994) found that the carcases of shorn lambs had lower TVC after dressing than "woolly" lambs. However, crutching did not reduce the numbers of bacteria on the carcase (Roberts 1980). Additional information in relation to the influence of production factors is presented in the following sections on specific hazards and indicator organisms.

2.4.5 Contamination from Saleyards/Lairages

Recent studies have demonstrated substantial capacity for cross contamination of microbial hazards between animals' hides at saleyards and at the abattoir. Transmission from cattle hides of selectively contaminated animals to their cohorts increased from 9% to 50% at saleyards, and from 11% to 83% at the abattoir, for hides before skinning and to 89% for skinned carcases (Collis et al 2004). The role of environmental contamination from contaminated lairages was found to be important. Stock that had not been selectively contaminated had a high prevalence of hide contamination pre-skinning after passing through the lairage/slaughter process following the selectively contaminated animals. This work extends earlier findings of contamination by food borne pathogens of cattle lairage floors (50%), stun-box floors (22%), sheep unloading ramp floors (33%) and pen floors (22%) (Small et al 2002). The authors conclude that the stun box and roll-out area was likely to play a substantial role in this cross contamination between lots as observed earlier by McGrath and Paterson (1969). Tutenel et al (2003) conclude that hide-to-hide transfer of *E. coli* O157:H7 within lots from the same farm seems to be the most probable route, with contamination from slaughterhouse environment and faeces-to-hide being a lesser transmission route. However, none of the papers focus on quantifying this in the context of counts to enable an assessment of the proportional contribution to carcase contamination. *E. coli* O157 and *Salmonella* have been isolated from lairage environments in a study conducted in Australia involving one abattoir (MLA 2006). Samples from abattoir floors (24 samples) and abattoir pen rails (19 samples) were collected prior to cattle entering the pens. *E. coli* O157 was detected in 42% of samples collected from abattoir pen floors and 47% from abattoir pen sides (rails). *Salmonella* was isolated from 33% of samples collected from abattoir pen floors and 26% from abattoir pen rails (MLA 2006). Counts of these pathogens were generally low with maximum counts for *E. coli* O157 and *Salmonella* of 0.024 and <0.005 MPN/cm^2 for abattoir pen rails and 110 and 0.0093 MPN/cm^2 for abattoir pen floors respectively (MLA 2006). Evidence of direct contamination of animal hides from this study has yet to be determined.

However, the finding that pathogens survived on hides, in faeces and on lairage materials for >1 week indicates that pathogens can be carried over from one batch to another and/or from one day to the next (Small et al 2003). In support of this pathway of contamination are the findings of Midgley and Desmarchelier (2001) in Australia. They report contamination with EHEC strains different from those at the farm and propose these strains are most likely from the abattoir environment contaminated by animals slaughtered earlier. The same authors also observed that rain may influence the rate of excreting STEC within a feedlot. The observation of a rainfall effect has not been scientifically determined, but further anecdotal evidence has been found in a recent study which looked at the numbers of *E. coli* in samples collected from a feedlot in 3 different trials (A, B & C; MLA 2006). There were significant differences in counts of *E. coli* in the feedlot environment between the different trials, suggesting variable environmental conditions between the trials. Weather conditions differed with Trial A conducted under drought conditions, Trial B after drought breaking rain and Trial C under prolonged wet weather conditions. *E. coli* counts in samples collected at the feedlot from cattle and the environment were significantly lower in trial A than in the other trials. In both trials where *E. coli* O157 was detected (B & C), it had been wet and raining in the previous week. The numbers of *E. coli* and detection of *E. coli* O157 both appeared to be affected by the wet weather, with *E. coli* O157 more prevalent in samples from the trials conducted after rain (MLA 2006). Wet weather has been implicated as an important factor in environmental contamination leading to human disease (Howie et al 2003) and rainfall may assist in the spread of microorganisms through the environment (Gagliardi & Karns 2000).

Additionally, when comparing cattle and sheep abattoirs, the overall prevalences of *E. coli* O157 in the lairage and on hides in the cattle abattoir were markedly higher than the respective prevalence of this pathogen in lairages and on pelts in the sheep abattoir. Similar, but less marked trends were observed for *Salmonella*. However, the proportional contribution to overall carcase hygiene from this pathway of contamination is uncertain. In this context a re-analysis of Australian sheep slaughter hygiene indicator counts indicated greater between-lot variation than within-lot variation (Kiermeier & Pointon unpublished). However, it needs to be noted that the different lots in this study were collected over an 18-month period from four abattoirs, and that the between-lot variation could partially be explained by the different lot characteristics. However, the similarity of microbiological contamination within lots is nevertheless consistent with the observations that individual animal tag-scores are similar within lots (Jordan et al 1999). In contrast, Collis et al (2004) and Avery et al (2004) showed significant between-lot cross contamination, when consecutive lots were monitored within a simulated saleyard and an abattoir lairage.

2.4.6 Industry Programs

The Australian industry collects and analyses carcase samples for verification of process control systems and to satisfy market access issues. AQIS requires export establishments to test beef and smallstock carcases for generic *E. coli* (biotype 1) and *Salmonella* and encourages them to test for TVC (MLA 2003 a,b). This requirement was introduced in 1997 in response to the FSIS PR-HACCP Final Rule, also known as Mega-Regs. Most domestic establishments test carcases for TVC and generic *E. coli*. The European Commission promulgated legislation in June 2001 requiring member countries to test carcases for TVC and *Enterobacteriaceae*. However, there is provision in the legislation for the competent authority to approve testing for *E. coli* instead of *Enterobacteriaceae*.

2.4.7 Conclusion

From the preceding evidence it can be concluded, within the context of HACCP (Gill 2000; Horchner et al 2006), that minimisation of dirty animals entering abattoirs is justified to reduce carcase contamination with visible contamination and microbial hazards, and to enhance the microbiological hygiene of the carcase.

2.5 Beef

2.5.1 *E. coli* O157/STEC

E. coli are found in all slaughter classes, however STEC are less commonly isolated. Some limited studies on the prevalence of STEC have been undertaken in goats, sheep and cattle in Australia (Table 1). However, it is difficult to compare between different studies as different methods were used and will affect the results. With this in mind, caution must be exercised when comparing the prevalence of STEC and *E. coli* O157 from the different studies shown in Table 1. Food Science Australia (1997) and Midgley and Desmarchelier (2001) found that STEC could be isolated from 19% of 95 and 16% of 50 cattle hides at slaughter, but there was evidence of STEC (in the form of Shiga toxin genes) on up to 80% of the hides. Recent studies on 139 cattle in a feedlot from the US have shown that *E. coli* O157 contamination of cattle hides can be as high as 73% (Keen & Elder 2002). From these high rates of hide contamination, it is important to ensure contamination of the carcase from the hide is minimised during slaughter and processing.

Recent studies on the prevalence of one serotype of STEC, *E. coli* O157, have found higher rates of animal contamination than previously expected, as new and more sensitive methods are used for detection (Table 1). These studies used 10g faecal samples for testing followed by the use of immunomagnetic separation (IMS) for detection of *E. coli* O157. *E. coli* O157 was found in 23% of faecal samples from 3,162 cattle in feedlots in the USA (Smith et al 2001). Another study on animals at slaughter found 28% of faeces from 327 animals contained *E. coli* O157 (Elder et al 2000). In addition, *E. coli* O157 has been found in the oral cavity of 75% of 139 cattle in a feedlot of which *E. coli* O157 was detected in the faeces of only 60% of the animals. When hides of these animals were also examined for *E. coli* O157, the combination of hide, oral cavity and faeces testing found *E. coli* O157 on 94% of the 139 animals tested (Keen & Elder 2002). The implied relationship between farm/hide strains to carcases was confirmed in a companion genotyping study (Barkocy-Gallagher et al 2001). This new information has resulted in FSIS requiring establishments to *Reassess their HACCP plans to determine whether E. coli O157:H7 contamination is a hazard reasonably likely to occur* (Federal Register document 9 CFR Part 417, October 7, 2002). An Australian study, using similar methodology to the USA studies, found 32% of 140 cattle faeces collected in holding pens from a single abattoir contained *E. coli* O157. Enumeration of *E. coli* O157 from 24 of the positive faecal samples found counts varied from undetectable levels (<3 MPN/g) to 2.4×10^4 MPN/g (Fegan et al 2004).

A more recent national survey of prevalence of *E. coli* O157 found in cattle faeces at an Australian abattoir (Fegan et al 2004) found 10% of 155 grass-fed cattle and 15% of grain-fed cattle positive (Table 1). There was no significant difference between the *E. coli* O157 counts of the grass-fed and grain-fed cattle. These data support similar earlier observations of Hancock et al (1997).

2.5.1.1 Gut colonisation

The location of *E. coli* O157:H7 in the gastrointestinal tract has been shown to be the distal rectum rather than the rumen (Grauke et al 2002; Naylor et al 2003, Low et al 2005). As a consequence of this specific distribution, *E. coli* O157:H7 is predominantly present on the surface of the faecal stool, in contrast to other *E. coli* serotypes being present at consistent levels throughout the large intestine and equally distributed in the stool (Naylor et al 2003). This is supported by Robinson et al (2005) who found the distribution of *E. coli* O157 in faecal pats was not heterogeneous, probably as a result of *E. coli* O157 contaminating faeces in contact with the gut wall. However, not all cattle are colonised by *E. coli* O157 at this site and the relationships between colonisation and shedding are not fully understood. Consequently, the ecology of shedding may not reflect that of *Salmonella* and generic *E. coli*.

2.5.1.2 Animal age

Age appears to influence shedding. Studies of dairy calves in Queensland found that weanlings not only shed STEC more frequently than other cattle on the dairy farm, but a greater proportion of STEC shed are of public health significance, including *E. coli* O26:H11 and *E. coli* O157:H7 (Cobbold & Desmarchelier 2000; Cobbold & Desmarchelier 2002). These findings are consistent with other reports of younger cattle on dairy farms being more likely to shed STEC (Wells et al 1991; Wilson et al 1993; Zhao et al 1995; Heuvelink et al 1998) and the importance of weaned dairy and beef calves as a source of contamination (Buchko et al 2000; Laegreid et al 1999). Consistent with these age effects in calves, is the observation by van Donkersgoed et al (1999) of higher *E. coli* O157:H7 in beef yearlings than in cows.

2.5.1.3 Seasonality

Seasonal variations in the shedding of STEC/ *E. coli* O157:H7 by cattle have been observed in different studies in different northern hemisphere countries. In the UK peaks were observed in spring and late summer (Chapman et al 1997), with a summer peak being identified in the US (Hancock et al 1994) and Belgium (Tutenel et al 2003). Van Donkersgoed et al (1999) found the prevalence of *E. coli* O157:H7 highest in the summer months in Canada. Bonardi et al (1999) found marked decreases toward the cooler months in Italy. There have been no scientific studies to determine the seasonality of STEC/*E. coli* O157:H7 shedding in Australia.

2.5.1.4 *E. coli* O157:H7 supershedding

The observation of “supershedding” in cattle has been observed by several investigators (Fegan et al 2004, MLA 2006, Low et al 2005, Omisakin et al 2003, Robinson et al 2004). In an Australian study at least two samples had counts of *E. coli* O157 that were similar to the generic *E. coli* count, suggesting that in these particular animals, *E. coli* O157 was the predominant *E. coli* type. The highest *E. coli* O157 recorded was 1.1 x10^5 MPN/grm. The risk of carcase contamination from such supershedders was investigated by Fegan et al (2005a). In this report the group of grass-fed cattle which contained the highest faecal (7.5 x 10^5 MPN/grm) and hide (22 MPN/cm^2) counts in any individual animal was the only group in which *E. coli* O157 was isolated from the carcase, suggesting a link between the numbers of *E. coli* O157 present and the risk of carcase contamination. A similar observation was made in a subsequent study where the carcase of an animal shedding 4.6 x 10^5 MPN/g of faeces became contaminated. It is unclear what causes the high shedding of individual cattle as this animal was shedding only 460 MPN/g of faeces 30h prior to slaughter (MLA 2006). Further information is required to determine the impacts of supershedding animals on transmission of *E. coli* O157 to other animals and the causes of supershedding.

2.5.1.5 Environment

The environment can become contaminated with STEC and maintain transmission of the bacteria within and between animal groups. STEC have been found in soil and water samples from Australian cattle farms and feedlots (Cobbold & Desmarchelier 2000, Midgley & Desmarchelier 2001). STEC can survive in manure and on pasture for several months leading to the contamination of subsequent animal populations grazing on the contaminated fields (Fukushima et al 1999; Ogden et al 2002). STEC survival in faeces is affected by temperature, with STEC detected for longer periods in faeces stored at lower temperatures eg 10°C and 25°C, than at higher temperature eg 37°C (Food Science Australia 2000). STEC can contaminate and grow in some cattle feeds (Lynn et al 1998), allowing transmission of STEC between animals (Hancock et al 1998). Birds and insects can also carry STEC (Wallace et al 1997; Iwasa et al 1999; Schmidt et al 2000) and these may contribute to the spread of STEC within and between different farms. Midgley and Desmarchelier (2001) also observed that rain may influence the rate of excreting STEC within a feedlot.

2.5.1.6 Transport

Midgley and Desmarchelier (2001) found unique serotypes of STEC in cattle at slaughter in Australia, which had not been found in the animals throughout fattening in a feedlot. This suggests that contamination of cattle with STEC can occur during transportation or during holding at the abattoir (Midgley & Desmarchelier 2001). Further evidence for contamination of animals during transport is found in Midgley (2000) where STEC were isolated from 65% of 20 samples from trucks prior to loading of feedlot cattle destined for slaughter.

An effect of transport on the shedding of cattle *E. coli* O157 from a feedlot and farm has not demonstrated any increase (MLA 2006, Minihan et al 2003). Barham et al 2002 report levels on hides (18%) and in faeces (9.5%) at the feedyard decreased ($P>0.05$) to 4.5% and 5.5%, respectively, upon arrival at the abattoir. Minihan et al (2003) similarly report the prevalence of *E. coli* O157 at farm, post transportation and lairage was 18%, 13% and 12% for one cohort and 1.7%, 1.7% and 0% for another. However, a recent study showed the prevalence of *E. coli* O157:H7 excretion was significantly increased in calves subjected to long-haul transport (15 hrs) without preconditioning (Bach et al 2004).

E. coli O157 has been isolated from trucks used to transport cattle to slaughter in Australia, with 26% of 27 truck floor samples and 11% of 27 truck side samples containing the pathogen (MLA 2006). Counts of *E. coli* O157 in the samples were generally low with maximum counts of 410 MPN/cm^2 on truck sides and 43 MPN/g for material collected from truck floors (MLA 2006).

The complexity of **developing effective procedures** before slaughter to minimise contamination of carcases with pathogens is underscored by recent results on *E. coli* O157 carriage at slaughter. Historically, *E. coli* has been used as a surrogate for the likely contamination with faecal pathogens. A national survey of 155 grass-fed and 155 grain-fed cattle found no correlation between the generic *E. coli* count and the *E. coli* O157 count in faeces at slaughter (Fegan et al 2004). Reliance on procedures developed to minimise microbial loads on carcases (TVC, Coliforms, *E. coli*) will assist in achieving pathogen control but it is not possible to set critical limits for indicators that are both easily achievable and ensure that pathogens are absent.

Therefore, inclusion of hide/fleece/skin cleanliness in an on-farm food safety program would be on the basis of current regulations rather than on the implementation of a HACCP-based approach for specific pathogens (Horchner et al 2006).

In a recent authoritative review of *E. coli* O157 (the most studied EHEC, and that of greatest public health and economic importance) the authors highlight the incompleteness of current understandings about the organism's ecology in live animals and agricultural environments (Rasmussen & Casey 2001). They suggest that knowledge about this organism is currently far too incomplete to devise on-farm interventions that would be practical and deliver a meaningful reduction in risk.

2.5.2 Salmonella

Cattle frequently carry *Salmonella* in their gastrointestinal tract. A study conducted by Food Science Australia has found 16% of 68 animals presented for slaughter at a single Queensland plant shed *Salmonella* (Fegan et al 2005b). All samples were analysed using immunomagnetic separation technology (IMS). In a preliminary study the type of diet did not affect the carriage with 67% (47/70) of grass fed animals and 50% (35/70) of grain fed animals positive for *Salmonella*. Counts in faeces (24) were also estimated using IMS/MPN, with ranges of and <3 to 9,328 MPN/g and <3 to 427 MPN/g for grass-fed and grain-fed animals respectively. In a recent national survey (Fegan et al 2004) no significant difference in the prevalence of *Salmonella* between grass-fed (5% of 155 cattle) and grain-fed (9% of 155 cattle) faeces collected at slaughter was shown. There was no significant difference between the counts of *Salmonella* between the two production systems, with counts generally <10/g, and the highest of $2.8x10^3$/g.

Transportation has an effect on the shedding of *Salmonella*. Barham et al (2002) showed the average prevalence levels of *Salmonella* spp. of cattle on hides (6% of 200 feedlot cattle held in 10 pens) and in faeces (18%) increase during transportation to 89% and 46%, respectively, at the feedyard. Puyalto et al (1997) observed that the most influential step for contamination of hides with *Salmonella* was during transportation to the abattoir. In a recent study on cattle transported for short times (<2 hours) there were no *Salmonella* isolated from the hides of cattle either before or after transport and lairage (MLA 2006).

Barham et al (2002) found 75% of 46 truck floor samples to be contaminated with *Salmonella. Salmonella* has been isolated from samples collected from transport vehicles in a small study from Australia, with 4% of 27 truck floors and 11% of 27 truck sides yielding *Salmonella* isolates (MLA 2006). Counts of *Salmonella* from the trucks were below the limits of detection for the enumeration method, with <0.003MPN/cm^2 on truck sides and <3 MPN/g for material collected from truck floors (MLA 2006).

The time of transportation has also been shown to affect the percentage of infected cattle (Grau & Brownlie 1968). Transportation times up to 48h had little effect on the prevalence of *Salmonella* in the rumen of cattle; after this time the number of shedding animals increased dramatically. Feeding of cattle prior to slaughter further increased the prevalence. Overseas studies have shown that animals transported over long distances are likely to be "dirtier" than animals transported over short distances (Davies et al 2000).

2.5.3 Hygiene indicators

When cattle and sheep are receiving a regular daily ration *Salmonellae* and *E. coli* are normally eliminated rapidly from the gastrointestinal tract. Restriction of the food intake or interruption of feeding for one or more days retards their elimination or even permits their growth in the rumen. Resumption of feeding after starvation can further stimulate growth of these organisms and increase shedding (Brownlie & Grau 1967; Grau et al 1969; Reid et al 2002). Diet and starvation has been shown to increase the shedding of *E. coli* (Grau et al 1969; Cray et al 1998, Gregory et al 2000; Jacobson et al 2002). These studies have verified earlier experimental fasting observations, and extended these to developing strategies to minimise bacterial buildup and reduce the spreading of faeces in pre-slaughter cattle. Fasting for 24 hours followed by 2 hours of transport and 16 hours lairage significantly increased rumen and faecal *E. coli* at slaughter. This suggests that extended periods of fasting in commercial cattle slaughter operations should be avoided where possible. Red clover hay and en-silaged pasture (haylage), were the most effective pre-transport diets for reducing *E. coli* counts in the rumen (to <1 log/grm). This was most likely due to the production of *E. coli*-toxic volatile fatty acids, and possibly additionally for haylage, the direct ingestion of lactate produced during the fermentation of the haylage bale. The reduction in rumen and faecal *E. coli* in lucerne hay-fed, and to a lesser degree, in meadow hay-fed heifers, may also be coumarin associated. Pasture-fed animals (not fasted) had runnier faeces and more surface soiling on the hide. Fasted animals (40 hrs total off feed to slaughter) produced less effluent on the truck, but they had high levels of *E. coli* in their rumens and faeces at slaughter.

Gregory et al (2000) and Jacobson et al (2002) wisely recommend cost:benefit analyses of pre-transport feeding, taking into account carcase weight and reduced carcase contamination risks, versus possible truck cleaning costs.

E. coli comprises a greater proportion of the total aerobic flora of gut contents than it does of wool (Grau 1979). Certain dressing operations are likely to lead to contamination of specific areas of the carcase, resulting in very uneven distribution of contaminating organisms (Grau 1979). The apparent degree of contamination of carcases or sites depends on the group of microorganisms selected as indicators (Grau 1979).

Vanderlinde et al (1995) found higher numbers of *E. coli* on the flank, brisket, round and neck and concluded that the hide was the main source of contamination.

Lot-fed cattle, particularly British breeds such as Angus, are frequently visibly dirtier at slaughter than *Bos indicus* breeds. Animals transported over long distances are likely to be dirtier than animals transported over short distances (Davies et al 2000).

Washing of animals has been considered desirable to reduce the likelihood of contaminating carcases with pathogens during slaughter and dressing. Although it is not a formal Export Meat Orders requirement, AQIS encourages export plants to wash cattle before slaughter as perceived good manufacturing practice. To our knowledge, all export abattoirs wash cattle before slaughter and/or require feedlots to wash them prior to delivery. As well, many domestic abattoirs also wash cattle. However there is little if any evidence of the benefit of washing. In a trial on *Bos indicus* cattle in SE Queensland, Eustace and Vogler (1998) found that washing slightly increased total counts and had no effect on the prevalence of detection of coliforms or *E. coli*. Eustace and Vogler (1998) found, in an export abattoir that the effect of shearing hair and filth off cutting lines before cattle were dressed had minimal effect ($p>0.05$) on the average total count on the dressed carcases and on the numbers of carcase samples on which coliforms or *E. coli* were detected.

US research on a chemical dehairing process has shown that it reduces visible contamination but the effect on bacterial load is variable – no effect on the carcase total counts coliforms and *E. coli* in one study (Schnell et al 1995) and significant reductions in TVC, coliforms and *E. coli* in another with artificially contaminated cattle hides (Castillo et al 1998).

In two US abattoirs Arthur et al (2004) demonstrated levels of TVC and to a lesser degree *E. coli* O157, prevalence on hides were significantly related to the respective levels on the corresponding carcases. These observations indicate that interventions focussed on reducing the number of bacteria and pathogens on the hide can have a large impact on the level of pathogens on the carcase.

2.5.4 Conclusion

The ecology of microbial build-up and opportunity for carcase contamination varies:

- between hazards within the same stock type/pathway-to-slaughter scenario, and
- between stock type/pathway-to-slaughter scenarios.

An important research priority for the future is to take these findings further, and develop pre-slaughter management strategies that minimise the large numbers of undesirable bacteria in wet, highly dispersible faeces. Recommending a standard feed curfew period will not provide a simple solution. Feed curfew periods before slaughter should help to reduce the prevalence of pen stain and other forms of faecal contamination on the body surface, but they will increase the burden of unwanted bacteria when faecal contamination does occur.

2.6 Sheep

2.6.1 *E. coli* O157/STEC

STEC are widespread among animal populations within Australia, as shown in Table 1. A study of lamb and mutton properties found 90% of 40 properties contained animals that carried STEC in their faeces (Djordjevic et al 2001). However, very low levels of *E. coli* O157 have been found on farm and at the abattoir. The number of STEC in lamb faeces was found to be ~1 log higher than adult animals, but the number of STEC decreased to levels similar to those of adults after weaning (Food Science Australia 2000). Chapman et al (1993) demonstrated a higher rate of shedding by sheep in summer. In experimental studies conducted on naturally contaminated sheep, no effect was demonstrated of feed withdrawal or diet change from grass to grain on the magnitude of faecal shedding of *E. coli* and STEC. The concentrations of total *E. coli* and STEC shed by individual animals varied significantly with major differences consistently attributed to a small number of animals. (Food Science Australia 2000).

E. coli O157 has been infrequently isolated from sheep within Australia (Djordjevic et al 2001, Food Science Australia 1997), although the application of sensitive and specific methods (such as immunomagentic separation using large amounts of faeces) have not yet been used for studying prevalence in sheep. Data from other countries suggests sheep can be a source of *E. coli* O157 contamination that may lead to human disease through direct contact with faeces (Ogden et al 2002). Further information on the prevalence and numbers of *E. coli* O157 carried by sheep and lambs in Australia is required.

2.6.2 Salmonella

Withholding sheep from feed or feeding after starvation can result in a 10^3 to 10^6 fold increase in the level of *Salmonella* in the rumen and faeces of sheep (Grau et al, 1969). Grau and Smith, (1974) showed that the level of *Salmonella* shed by sheep increased with holding time at the abattoir. In heavily contaminated pens the levels increased by about 1-log unit per day. The rate of contamination of the fleece also increased rapidly, after three days nearly all of the animals were contaminated. In less heavily contaminated pens the levels increased more slowly and fewer hides became contaminated (~20%). Contamination of carcases with *Salmonella* followed a similar pattern, with the number of positive carcases increasing with holding time prior to slaughter. Serotypes isolated included Adelaide, Havana, Meleagridis, Oranienburg and Derby. It was concluded that the fleece was the primary source of contamination of carcases. *Salmonella* was also isolated more often after evisceration (Grau 1979) inferring this to be a major point of carcase contamination.

2.6.3 Hygiene indicators – *E. coli* biotype 1

Grau (1979), showed that while the fleece was the primary source of bacterial contamination on sheep carcases, *E. coli* numbers increased 100-fold after evisceration. Grau reported that *E. coli* made up only a small proportion of the total bacterial population on the fleece of sheep (0.003%).

Biss and Hathaway (1996b) found that the use of a pre-slaughter wash on lambs to improve their suitability for slaughter resulted in increases in the mean aerobic counts and in the counts of *E. coli* for virtually all the carcases.

Roberts (1980) found that there was no association between the final numbers of bacteria on lamb carcases in wet or dry weather, indicating that there were probably no seasonal influences on the microbial contamination of livestock. There was also no association whether the lambs were crutch-shorn or not. Hadley et al (1997) found that hygiene indicator counts were 2 log units higher on carcases from extensively soiled and wet 10 month old unshorn sheep, when compared with those from clean and dry 4 month old lambs. Thus it appears that “spring lambs”, reared and transported under conditions that avoid soiling of the fleece, can provide carcases of superior microbiological condition (Gill 2004). Gerrand (1975) considered that contamination from ingesta spill/leaks is less than that derived from the fleece. However, increased counts in faeces due to time-off-feed, may lead to increased hide/fleece counts via a secondary contamination.

There is a belief that the microbiology of sheep carcases is affected by season. The quality and quantity of spring feed is associated with scouring in ovines which transfers during pelt and viscera removal. In support of the seasonal effect is the strong trend seen from the ESAM database (MLA 2003a,b) for ovines over 2000-2002, with *E. coli* prevalence peaking in July-September consistently each year (Sumner & Kiermeier 2006, MLA industry report, submitted).

While demonstrating only small effects of pre-slaughter management on carcase hygiene, Duffy et al (2000) conclude that; *greatest control over carcase contamination was exerted within the packing plant through the use of good manufacturing practices and in-plant microbiological interventions. Of course, these pre-harvest, management practices can make a positive contribution towards improving the safety of lamb, but cannot be solely be relied upon to control contamination (i.e. a critical control point).*

2.6.4 Conclusion

Reliance on procedures developed to minimise microbial loads on carcases (TVC, *E. coli*) will assist in achieving pathogen control but it is not possible to set critical limits for indicators that are both easily achievable and ensure that pathogens are absent.

Withholding feed before slaughter leads to an increase in rumen pH which in turn favours the multiplication and growth of undesirable enteric bacteria within the gut of the animal. Pre-slaughter fasting can increase this bacterial burden in both faeces and rumen contents.

Notwithstanding the latter point, fasting reduces visible contamination of the surface of the animals, and facilitates hygienic dressing. Animals that are fasted before slaughter are less likely to defecate near to the time of slaughter, and so are less likely to contaminate themselves, their environments and other stock during the pre-slaughter period. Putting these points together, faecal or rumen contents contamination is less likely to occur if animals have been adequately fasted, but when it does occur, the bacterial load is likely to be more hazardous.

2.7 Goats

2.7.1 *E. coli* O157/STEC

Only limited data on the prevalence of STEC in goats in Australia is available (Table 1). STEC have often been found in goats in studies from other countries, with isolation rates between 48 and 74% (Beutin et al 1993;Cobeljic et al 2005; Cortes et al 2005). *E. coli* O157 has been isolated from goats in other countries (Chapman et al 2000; La Ragione et al 2005) and from Australia (Food Science Australia, person. communication).

2.7.2 Salmonella

Salmonella are commonly found in all slaughter classes. Goats appear to have higher carriage rates than cattle. A Food Science Australia/MLA study on the ecology of *Salmonella* in goats (Vanderlinde et al 2003); found that a large percentage of animals carried *Salmonella*, either in their rumen or faeces. Four mobs of goats were sampled from two abattoirs in Queensland on two occasions. Rumen content was contaminated in 72 of the 121 samples analysed (59.5%), while the faeces were contaminated 57% (68/120) of the time. The study also indicated feral animals may be more often contaminated than domestic animals, 23/40 (57.5%) and 2/40 (5%) respectively. However, the sample size was small and other confounding factors were not controlled, making the conclusions unreliable.

Salmonella were isolated (7/20) from goat carcases immediately after hide or hair removal (Vanderlinde et al 2003) suggesting that contamination is from material associated with the hide of these animals. The same authors report a transport effect, with positive faecal shedding rates rising from 10% to 47%; however, details of the transport time were not reported.

2.7.3 Hygiene indicators – *E. coli* biotype 1

No data on generic *E. coli* (biotype 1) is currently available. Consequently, no comments about risk factors can be made.

2.7.4 Conclusion

While only limited data exist for goats it nevertheless appears that goats have higher levels of contamination than other stock types. Consequently, additional interventions may be warranted.

2.8 Prospects for Dietary Interventions

In relation to "clean-out" and faecal consistency Gregory et al (2000) evaluated 4 treatments in which pasture-fed steers were fed for 48 or 24 h on hay, taken from pasture, or fasted 24 h before a 2-hour drive to an abattoir, where they were held overnight before slaughter. The 24-hour fast had apparently removed a substantial part of the contents of the digestive tract because the wet weight of excreta in the truck for the respective fed treatments was 7.2, 4.7 and 5.8 kg, which greatly exceeded the 1.7 kg from the fasted animals. Similarly, the dry matter proportion in the rumen of the fed treatments was 9-11%, which contrasted with less than 6% for the fasted group. However, because of the additional water content, the weight of rumen contents in the fasted group, 34.5 kg, was within the range 26.0 to 40.6 kg of the other groups.

Weston et al (1983), Bass and Duganzich (1980) and Gregory et al (2000) observed that cattle fed high-quality temperate pastures which would have been processed through the rumen relatively quickly, gave rise to a relatively small residue. This situation would not be typical of cattle which subsist on more fibrous forages that accumulate in the rumen in greater amounts and are cleared from the rumen relatively slowly, for example the northern Australian beef herds. There is no reason to believe that very large residues are cleared rapidly from the rumen during curfew. In the absence of direct information on this topic it would seem safe to assume that animals fed tropical grasses would maintain a substantial residue in the rumen for a longer time than the cattle shown. If this is so, the impact of curfew on rumen functioning would diminish, with diminished consequences for the supply of nutrients to the tissues as well as the survival of a normal rumen population to revive feed processing when the animal moves into lairage.

The emergence of *E. coli* serotype 0157:H7 as a potentially more serious threat to the meat industry than *Salmonella* spp. may have an important influence on curfew policy. As Brownlie and Grau (1967) found with *Salmonella*, the withdrawal of feed for 6 to 48 h leads to an increase in *E. coli* numbers. From an extensive review, Callaway et al (2003) recommend the feeding of hay for the last few days in a feedlot to reduce the numbers of *E. coli* in faeces. However, as wisely pointed out by Jacobsen et al (2002) further cost-benefit analyses of pre-transport feeding, taking into account carcase weight gains and related carcase contamination risks, versus possible truck cleaning costs, is warranted. However, since the ecology of *E. coli* O157 is different to *Salmonella* and *E. coli*, these conclusions may not translate.

In the work of Gregory et al (2000) the numbers of *E. coli* (log10/g) in the rectal contents of pasture-fed cattle were: when kept for 48 h on hay, 3.7; when moved directly from pasture, 5.0; and when fasted for 24 h, 6.6. This major increase in *E. coli* in cows fasted for 24 h greatly outweighs any benefits from the fourfold reduction in faecal mass from these animals. Hence, Gregory et al (2000) and, verified by Jacobsen et al (2002), recommend that animals at pasture should be fed on hay for a few days before transport, both to increase the dry matter content of faeces and thus, reduce the soiling of other animals, and also to reduce the content of *E. coli*. This seems a low cost solution to the problem, but there can be a delay of up to three days before livestock that were previously kept at pasture and then penned inside start to eat hay (Chapple & Wodzicka-Tomaszewska 1987).

The development of suitable vaccines, such as that available for *Clostridia*, may prove to be the best solution. An alternative under discussion is to give animal's exposure for 24 h to a solution of sodium chlorate. Enzyme systems in *E. coli* convert the chlorate to chlorite with fatal consequences to the microbe (Callanan et al 2002). Jacobsen et al (2002) demonstrated that coumarin from hay in combination with volatile fatty acids may contribute to lower rumen and faecal *E. coli* counts of lucerne and meadow hay-fed cattle.

Diet can also influence the shedding of STEC through altering the rumen pH and concentration and types of volatile fatty acids in the rumen and colon (Duncan et al 2000). The composition of the diet (high in roughage, such as pasture and hay diets, or high nutrient diets such as those containing grain) can affect STEC shedding. During the feedlot studies by Midgley et al (1999), Midgley and Desmarchelier (2001) and Food Science Australia (1997), the greatest variability in prevalence of STEC was observed during the first few weeks after entry into the feedlot during feed ration changes. This effect was also reflected in the *E. coli* counts during the feed changes.

There is currently some debate in the scientific community about whether diet can be manipulated to decrease the prevalence of STEC. *E. coli* count in sheep faeces was found to be greater than in cattle faeces, and grain-fed cattle had significantly increased *E. coli* counts, while feeding grain to sheep had no effect on the number of *E. coli* in faeces (Food Science Australia 2000). When STEC were enumerated in faecal samples, a significantly higher number was found in sheep than in cattle faeces, but no effect of diet was shown. However, only a small number of animals were tested and there was a large and significant variability between the individual herds and flocks sampled within each animal group, and also between individual animals (Food Science Australia 2000). The number of STEC in cattle and sheep faeces is shown in Table 2.

2.9 Conclusion

Time-off-feed including an on-farm Curfew for cattle for as little as 24 h can result in increasing levels of *Salmonella* spp. and *E. coli* in the gastrointestinal tract. When hay fed cattle (with no feed curfew pre-transport) were compared to pasture fed cattle with 40 hours off-feed, the latter curfewed cattle had a 3 $\log_{10}$ increase in *E. coli* counts above hay-fed, non-curfewed stock .

Off-feed curfew, thus, may increase the threat to human health through the contamination of carcases when cattle and sheep are slaughtered. Although other options for managing pathogens are being explored, the feeding of slowly digested roughage, for example hay, prior to transport is the simplest and probably the cheapest option if the stock will eat it. Curfew on-farm may thus be contraindicated in some scenarios.

Using current slaughter practices a percentage of the carcase is directly or indirectly contaminated with contents of the gastrointestinal tract. The degree of contamination is likely to be linked to the carriage rate of the animal slaughtered, the degree of difficulty in dressing the carcase and the slaughter practices and procedures employed. The number and distribution of bacteria on the hides of animals prior to slaughter is highly variable, it is therefore not surprising that contamination of the carcase is also variable.

Uncertainty exists in relation to the extent to which increased counts in faeces resulting from extended total time-off-feed impact on “unseen” carcase hygiene and pathogen levels.

2.10 Pre-slaughter Assessment Tool (PAT)

A Pre-slaughter Assessment Tool has been developed to conveniently summarise the complexity of contributing factors inherent to the various microbial hazards, stock types (including production systems) and pathway-to-slaughter scenarios.

In summary, PAT scores represent the sum of relevant or “active” factors that increase and decrease microbial hazard build-up for each scenario. However, the relative impact on eventual carcase contamination resulting from individual factors, and combination of factors for each scenario, **cannot** be inferred from these scores.

The combinations of contributing factors should, therefore, be limited to gaining an overview of the factors operating in each scenario as an aid to guide selection of the most appropriate control procedure(s) for each scenario.

Off-feed “curfew” is practiced on-farm to reduce soiling during transport and optimise hide/fleece cleanliness at slaughter. In microbial terms it represents only one component of pre-slaughter management of livestock that influences the microbial status of the carcase. In this section a scoring tool has been developed, using Microsoft Excel, for the contributing factors to provide a basis for rating stock type/pathway-to-slaughter combinations (Table 3). Using the foregoing review to answer the scoring system questions enables identification of the combination of contributing factors for each scenario. For each combination the contributing factors for *E. coli* O157, *Salmonella* spp., and hygiene indicators is also scored (Table 3). By covering factors from mustering to shackling at the abattoir, the combination of “curfew” and other contributing factors can be evaluated. The approach also enables an overview of factors impacting within each combination to provide a basis for informing development of combination-specific control measures.

The Pre-slaughter Assessment Tool (PAT) is based on a scoring system which adds a score of +1, 0 and -1 for effects that have been documented to, or can logically be inferred to, increase, not affect, or decrease the levels of microbiological contamination (internal and/or external), respectively. The scores for each factor and hazard combination are given in Table 3.

It should be noted that no attempt has been made to quantify the severity of the effect of each factor on the microbial loadings (internal or external). This decision has been made mainly due to the rather limited information from currently available literature – most of the documented studies have been designed to assess a particular part of the pathway-to-slaughter system rather than to provide a comprehensive assessment. Hence, each factor considered here received the same weighting, and potential compounding effects (where the combination of two factors is greater than the sum of the individual scores) have been ignored.

For a particular stock type, the scores obtained with the tool should be used to give a ballpark rating of how good or bad a particular pathway-to-slaughter scenario is. As there are data gaps for some factors and combinations, it is advised that no comparisons across product types be made.

Several scenarios for beef and sheep pathways-to-slaughter have been evaluated with the help of the tool. The various pathways and times for each stage in the pathway are given in Table 4. The total times off-feed have been elicited with help of expert opinion, that is, from other members of the curfew team. Examples of the PAT output are shown in Figures 3 and 4.

For purpose of these scenarios the transport times were classified as short (< 5hours), medium (5-10 hours) or long haul (>10 hours). In addition, for cattle, young stock refers to animals of less than or equal to 12 months of age, while for sheep/lambs, young refers to animals of less than or equal to 6 months of age.

2.11 Data gaps – R&D Priorities

In summary, the contributions above indicate the incompleteness of current understandings about the proportional contributions of different pathways of contamination and the best point(s) where interventions deliver a meaningful reduction in risk. In general, knowledge about microbial hazards is currently far too incomplete to devise on-farm interventions that would be practical and deliver a meaningful reduction in risk. However, without specific interventions that effectively target major hazards (eg vaccines for EHEC) there is still a need to rely on generic controls.

In commissioning research, food borne hazard levels on retail-ready product (as well as carcases) should be taken into account, as risk managers need to determine the equivalence of alternative mitigation procedures on eventual risk.

It must be borne in mind that any recommendation of curfew time will influence the total time-off-feed that includes transport (saleyards) and subsequent lairage yarding. The impact of curfew also needs to be considered in relation to other contributing factors that apply to each stock type/pathway-to-slaughter scenario. While there is considerable variation between scenarios there is also considerable variation within these scenarios due to different ecologies of the hazards of interest.

Consequently, it is recommended to set a Performance Standard of minimal hide/fleece contamination, and let industry utilise the most effective and practical means for each combination to achieve this outcome. This will minimise direct contamination to the carcase from hide/pelt filth, and in doing so reduce potential contamination from faeces containing high levels of hazards due to extended periods off-feed.

- Accordingly, research priorities include:
- Targeted development of pre-slaughter interventions that are risk-based for:
    - lambs and cattle associated with the spring flush (including the type and duration of hay feeding to minimise runny faeces),
    - feeding strategies for long-haul stock (hay feeding and/or not implementing an off-feed curfew for stock coming from fibrous pastures)
    - measures to minimise supershedders of EHECs (*E. coli* O157).
- A cost:benefit analysis of pre-transport feeding, taking into account carcase weight and reduced abattoir costs to minimise carcase contamination risks, versus possible truck cleaning costs is warranted.
- Research on nutritional methods of manipulating the faecal flora of ruminants before slaughter, considering EHEC, *Salmonella* and carcase hygiene outcomes.

- Research on the type and duration of hay feeding, and the duration of fasting following hay feeding, in terms of the excretion of potentially pathogenic bacteria and reducing runny faeces.
- A strategy paper to be prepared on alternative feeds and feed supplements that could be used to reduce the excretion of undesirable bacteria in faeces during the pre-slaughter period. This would include suggestions on which prebiotics, probiotics and synbiotics should be tested, particularly in lot-fed cattle.
- Regional differences in relation to the time-off-feed, type of feed interactions should be investigated to quantify the proportionality of pathways of carcase contamination i.e. hide versus ingesta contributions to carcase contamination in long-haul grass-fed cattle in Northern Australia.
- It is recommended that abattoirs document their management of hide contamination.
- It is recommended that the cattle and sheep slaughter industry implement a recognised system of tag/dag scoring.

However, on a through-chain basis, greater focus on optimal dressing procedures (Kiermeier et al 2005; Kiermeier & Pointon unpublished) to minimise contamination with hazards and achievement of excellent microbiological status of carcases should receive greater emphasis than pursuing complex pre-slaughter controls that are subject to considerable variation in microbial efficacy.

2.12 Conclusions

There is no single epidemiology for food borne hazards and carcase contaminants in livestock from farm-to-slaughter. Within stock type/pathway-to-slaughter scenarios the patterns of build-up of “microbial populations of concern” vary. This variation also extends between these scenarios. Consequently, with this limited knowledge of the variability of microbial loads and the unknown proportional impact of various contributing factors, only broad control options may be proposed.

While off-feed curfew reduces the potential for faecal contamination of hides/pelts during transport, the additive effect of increasing time-off-feed (including on-farm curfew) on unwanted microbial growth produces a countervailing effect. This applies to both *Salmonella* and generic *E. coli*.

For *E. coli* O157 in cattle (and more so in sheep) the pre-slaughter epidemiology is less well understood. Preliminary evidence supports the occurrence of “supershedders” in cattle that may result in high numbers and high potential for within-lot contamination of both livestock and carcases. In terms of counts alone this may over-ride other contributing factors. In view of export market access specifications, intervention(s) for this contributing factor is of paramount importance to exporters of boxed beef trim (22% of carcase weight).

Hence, for minimal transmission of pathogens and microbial contaminants during carcase dressing, emphasis should be on clean hides/pelts in livestock presented for slaughter. This will minimise direct contamination to the carcase from hide/pelt filth, and in doing so, reduce potential contamination from faeces containing high levels of hazards resulting from extended periods off-feed.

This “cleanliness” or outcomes-based standard should be supported by the implementation of a hide/pelt scoring system that could be related to the economics of dirty hides/pelts (dressing and microbiological) including feedback of scores and financial penalties to producers. A caveat would be the need to adopt solid floors in transports to eliminate confounding results.

A Pre-slaughter Assessment Tool (PAT) was developed to provide a convenient way of defining the combination of “active” contributing factors for each stock type/pathway-to-slaughter scenario. PAT software scores represent the sum of relevant factors that increase and decrease microbial hazard build-up for each scenario. However, the relative impact on eventual carcase contamination of individual factors, and combination of factors for each scenario, cannot be inferred from these data. Nevertheless, industry stakeholders are provided with an overview of combinations of contributing factors to guide selection of the most appropriate control procedure(s) for each scenario.

Off-feed curfews prior to transport of up to 24 hours are indicated to minimise soiling of the hide/pelt, which is associated with efficient dressing and lower carcase microbial counts. When taking account of times associated with transport, potential saleyards and lairage at the abattoir, this pre-transport “cleanout” may also counter further hide/pelt contamination associated with increased microbial counts within livestock lots subjected to extended time-off-feed. This effect, though, may be less for stock with runny faeces.

Alternatively, as shown for cattle, feeding of specific hay varieties and forms for 48 hours prior to transport leads to reduced counts and firmer faeces with less soiling. Consequently, R&D should include evaluating feeding strategies to replace fasting for some stock type/pathway-to-slaughter scenarios (especially when runny faeces are a common problem).

It is recommended that cost:benefit analyses of pre-transport feeding, taking into account carcase weight and reduced carcase contamination risks, versus possible truck cleaning costs are undertaken.

Fasting and feeding effects for lot-fed cattle are less proven and require further evaluation, particularly in relation to the proportional contribution of sources of contamination (i.e. hide tag score versus changes in faecal shedding as a result of shipment/lairage effects).

The complexity of preventing hide/fleece soiling before slaughter is further compounded by stock on upper decks with runny faeces contaminating stock on lower decks when there are no solid floors. Here the solution lies with those responsible for provision of appropriate stock transport systems.

It cannot be assumed that pre-slaughter controls for generic *E. coli* and *Salmonella* will be effective for *E coli* O157/STEC from either grass or lot-fed production systems. The effect of pre-slaughter controls for sheep carcase hygiene is similarly unreliable. Therefore, greater focus should be on optimal dressing procedures to minimise hazards and the attainment of excellent microbiological status of carcases. These should receive greater emphasis than pursuing complex pre-slaughter controls that are subject to considerable variation in microbial efficacy, and as such, are unsuitable as Critical Control Points within a HACCP system.

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2.14 Appendices

Table 1: Prevalence of STEC and *E. coli* O157 in the faeces of different animals in Australia.

Animal	Place	Samples tested for	No. samples tested	Percent positive	Reference
cattle	abattoir	O157:H7	100	10	Fegan et al 2005a[d]
Cattle	Abattoir: National Survey				Fegan et al 2004[d]
grass - fed		O157:H7	155	10	
grain-fed			155	15	
Cattle	Abattoir	*E. coli* O157	140	32	MLA 2003d[d]
Cattle [a]	Farm	STEC	123	18.7	Hornitzky *et al.*, 2001
Cattle	Abattoir	STEC	251	3.6	Food Science Australia 1997 (STR001)
Cattle[a]	Farm	*E. coli* O157	123	0.8[b]	Hornitzky *et al.*, 2001
Cattle	Feedlot	*E. coli* O157	700	0.9	Midgley and Desmarchelier, 2001
Cattle	Feedlot	*E. coli* O157	50	2	Midgley and Desmarchelier, 2001
Dairy cattle	Abattoir	*E. coli* O157	505	0.2	Hallaran and Sumner, 2001
Dairy cattle[c]	Farm	*E. coli* O157	588	1.9	Cobbold and Desmarchelier, 2000
Dairy cattle[c]	Farm	*E. coli O26:H11*	588	1.7	Cobbold and Desmarchelier, 2000
Calves	Abattoir	STEC	105	12	Sidjabat-Timbunan and Bensink, 1997
Calves	Abattoir	STEC	165	12	Food Science Australia 1997 (STR001)
Sheep	Farm	STEC	216	42	Fegan and Desmarchelier, 1999
Sheep	Farm	*E. coli* O157	1623	0.1	Djordjevic et al 2001
Sheep	Abattoir	STEC	101	46	Sidjabat-Timbunan and Bensink, 1997
Sheep	Abattoir	*E. coli* O157	144	2	Fegan and Desmarchelier, 1999
Lambs	Abattoir	STEC	160	15	Food Science Australia 1997 (STR001)
Goats	Abattoir	STEC	77	27	Desai 2002

[a] diagnostic faecal samples submitted to vet lab for pathogen testing
[b] isolate of *E. coli* O157:H8 containing stx_2 and *ehx* (not typical of *E. coli* O157:H7)
[c] included heifers, milking cows and calves of various ages
[d] used more sensitive IMS method of detection with 10grm samples

Table 2: Enumeration of STEC and total *E. coli* in the faeces of animals from different sources[a]

Animal Group and diet	No. Faeces Tested	Count ($\log_{10}$ CFU/g)	
		STEC	**Total *E. coli***
Grain-fed cattle	40	3.24±2.15[b]	6.27±0.46
Grass-fed cattle	30	2.74±2.40	5.55±1.16
Dairy cattle	30	2.50±1.60	4.94±0.96
Grain-fed sheep	30	4.26±1.77	7.14±0.76
Grass-fed sheep	30	3.56±1.89	6.44±1.27

[a] from Food Science Australia, 2000 – STR021: Chapter 2
[b] Mean and Standard Deviation.

Table 3: Factors contributing to the microbial loadings for the various product categories and their effects – scores of +1 indicate increasing microbial loadings, 0 indicates no effect, -1 indicates a decreasing effect, and "no data" indicates that there are no existing data sources to asses the effect.

Factor	***E. coli* O157:H7**	***Salmonella***	**Generic *E. coli***
Species	Beef: **+1** Sheep & Goats: **0**	Beef & Sheep: **0** Goats: **+1**	All: **0**
Age	Beef & Sheep: young **+1** Goats: **no data**	Beef: young **+1** Sheep & Goats: **no data**	All: **no data**
Faeces consistency	All: pellet **0**; pad **+1**; runny **+2**	All: pellet **0**; pad **+1**; runny **+2**	All: pellet **0**; pad **+1**; runny **+2**
Seasonal effect of shedding	Beef & Sheep: Summer **+1**	All: **no data**	Beef & Sheep: **no data** Goats: **no effect**
Wool/Hair length	Beef: Long haired breeds **+1** Sheep: Wool length>5cm **+1** Goats: **no data**	Beef: Long haired breeds **+1** Sheep: Wool length>5cm **+1** Goats: **no data**	Beef: Long haired breeds **+1** Sheep: Wool length>5cm **+1** Goats: **no data**
Grain fed	Beef: **no difference** Sheep & Goats: **no data**	All: **no data**	Beef: **no difference** Sheep & Goats: **no data**
Pre-transport emptying	Beef: <12 h **+1**; >=12 h **0** Sheep & Goats: <24 h **+1**; >=24 h **0**	Beef: <12 h **+1**; >=12 h **0** Sheep & Goats: <24 h **+1**; >=24 h **0**	Beef: <12 h **+1**; >=12 h **0** Sheep & Goats: <24 h **+1**; >=24 h **0**
Stress effect of transport on shedding	Beef: **no difference** Sheep & Goats: **no data**	Beef & Goats: **+1** Sheep: **no data**	All: **no data**
Saleyard cross-contamination	All: direct **0**; saleyard **+1**	All: direct **0**; saleyard **+1**	All: direct **0**; saleyard **+1**
Lairage cross-contamination	All: **+1**	All: **+1**	All: **+1**
Supershedding	Beef: **+1** Sheep & Goats: **no data**	Beef: **+1** Sheep & Goats: **no data**	Beef: **+0** Sheep & Goats: **no data**
Wet hide / fleece (after washing?)	All: dry **0**; wet **+1**	All: dry **0**; wet **+1**	All: dry **0**; wet **+1**
Stunning to shackle	All: **+1**	All: **+1**	All: **+1**
Post-transport feeding	All: **no data**	All: no **0** yes & spell < 3 days **+1** yes & spell >= 3 days - **return to baseline prior to first transport**	All: no **0** yes & spell < 3 days **+1** yes & spell >= 3 days - **return to baseline prior to first transport**
Total Time off-feed (muster to lairage) [Does not include spell period of up to 3 days; spelling in excess of 3 days means that TToF = lairage time]	All: **no data**	All: <36h **+0** for @ additional 24h **+1**	All: <36h **+0** for @ additional 24h **+1**

Table 4: Pathway to-slaughter scenarios for each stock type indicating the number of hours animals spend at each stage to give total time-off-feed (Source: Expert Opinion).

Pre-slaughter activity	Beef feedlot, short-haul, direct	Beef, pasture, medium haul, direct	Beef, pasture, short haul, via saleyard	Beef, pasture, long haul, direct	Beef, pasture, long haul, via saleyard
Muster	1	1	2	4	4
Transport – on-enterprise					
Off feed curfew on-farm	10	10	10	12	12
Transport	2	10	5	24	24
Saleyard			24		30
Transport only if via saleyard			4		8
Spell +/- feeding					
Abattoir lairage	14	14	14	14	14

Pre-slaughter activity	Lambs, short haul, direct	Sheep, short haul, via saleyard	Mutton, long haul, direct	Mutton, long haul, via saleyard	Goats, direct
Muster	1	1	14	14	6
Transport – on-enterprise					3
Off feed curfew on-farm	16	16	14	14	24
Transport	4	4	18	18	16
Saleyard		24		12	
Transport only if via saleyard		3		3	
Spell +/- feeding					
Abattoir lairage	20	20	16	16	16

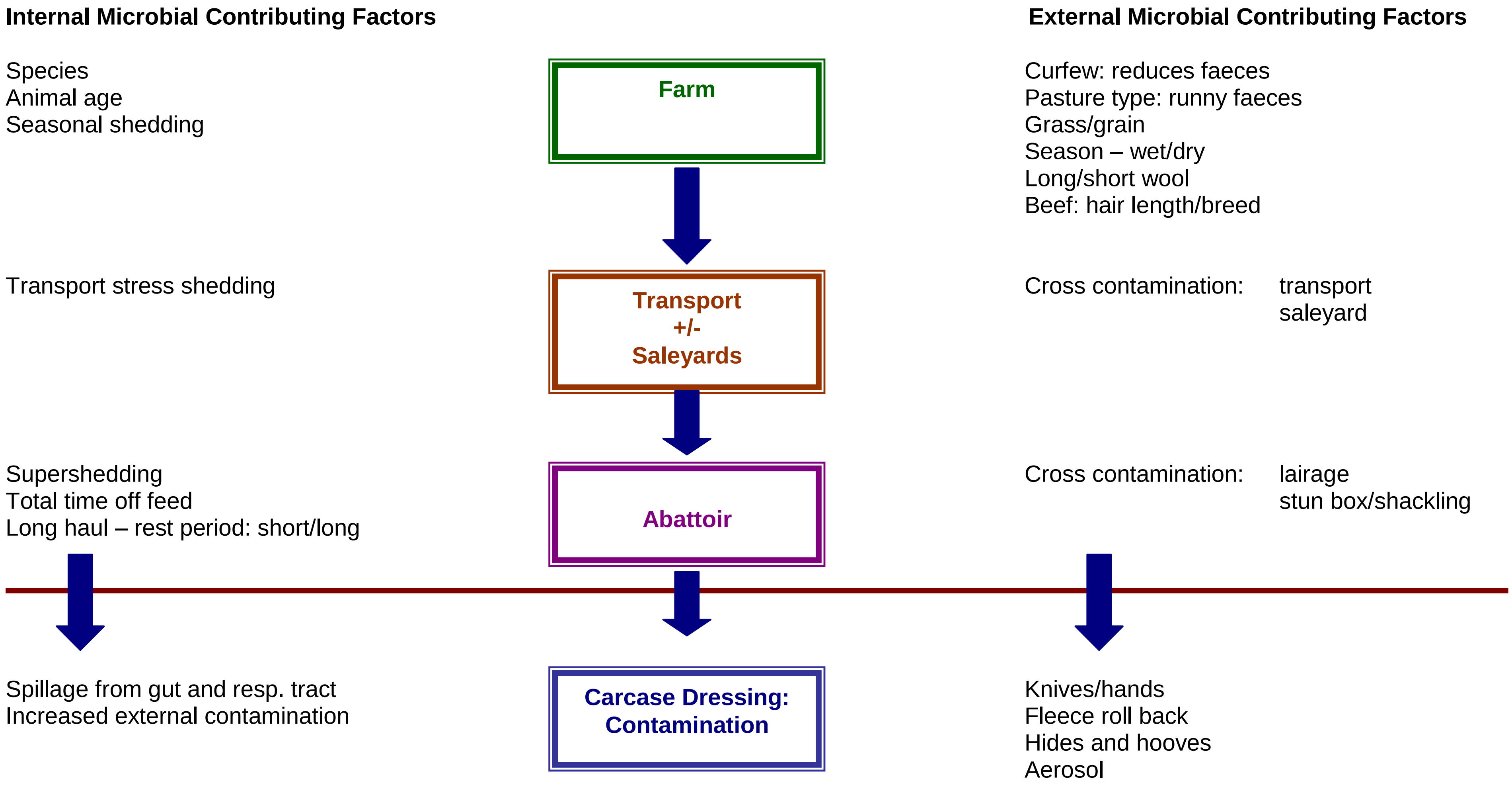

Figure 1: Pre-slaughter Process Model: Contributing Factors

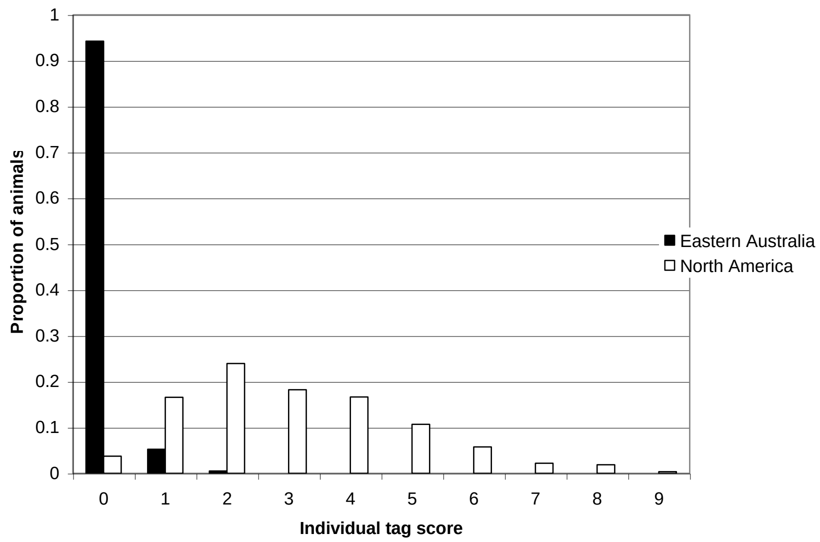

Figure 2. Comparison between tag scores for cattle slaughtered in Eastern Australia and tag scores for North American cattle

		E. coli O157	*Salmonella*	gen *E. coli*
Animal characterisics				
Species	Beef	1	0	0
Age	Old	0	0	
Faecal consistency	Pad	1	1	1
Season	Summer	1		
Long haired breed?	yes	1	1	1
Feedlot or pasture?	Feedlot	0		
Animal baseline score		4	2	2
On Farm				
Muster duration (hours)	1			
Curfew duration (hours)	10			
Pre-transport emptying (curfew >=12 hours)	no	1	1	1
Transport - Leg 1				
Transport duration (hours)	2			
Transport stress effect on shedding?		0	1	
Saleyard				
Are the animals sold via a saleyard or direct?	Direct			
Duration in saleyard (hours)?	0			
Saleyard cross-contamination	no	0	0	0
Transport - Leg 2				
Transport duration (hours)	0			
Spelling & Feeding				
Time off-feed (until arrival at abattoir)	13			
Are animals fed/spelled after transport?	no		0	0
If animals are spelled, how long (days)	0			
Return to baseline?			no	no
Transport & Saleyard Score		1	2	1
Abattoir Lairage				
Lairage duration (hours)	14			
Lairage cross-contamination		1	1	1
Total effective time off-feed			27	27
Time off-feed effect			0	1
Is super-shedding possible?		1	1	0
Wet hide (after washing)?	dry	0	0	0
Stunning/shackle cross-contamination		1	1	1
Total Score		**8**	**7**	**6**

Figure 3: Screen shot of PAT – Beef feedlot, short haul, direct

		E. coli O157	*Salmonella*	gen *E. coli*
Animal characterisics				
Species	Sheep	0	0	0
Age	Young	1		
Faecal consistency	Pad	1	1	1
Season	Summer	1		
Long wool (>5cm)?	no	0	0	0
Feedlot or pasture?	Pasture			
Animal baseline score		3	1	1
On Farm				
Muster duration (hours)	1			
Curfew duration (hours)	16			
Pre-transport emptying (curfew >=24 hours)	no	1	1	1
Transport - Leg 1				
Transport duration (hours)	4			
Transport stress effect on shedding?				
Saleyard				
Are the animals sold via a saleyard or direct?	Direct			
Duration in saleyard (hours)?	0			
Saleyard cross-contamination	no	0	0	0
Transport - Leg 2				
Transport duration (hours)	0			
Spelling & Feeding				
Time off-feed (until arrival at abattoir)	21			
Are animals fed/spelled after transport?	no		0	0
If animals are spelled, how long (days)	0			
Return to baseline?			no	no
Transport & Saleyard Score		1	1	1
Abattoir Lairage				
Lairage duration (hours)	20			
Lairage cross-contamination		1	1	1
Total effective time off-feed			41	41
Time off-feed effect			1	1
Is super-shedding possible?				
Wet wool (after washing)?	dry	0	0	0
Stunning/shackle cross-contamination		1	1	1
Total Score		**6**	**5**	**5**

Figure 4: Screen shot of PAT – Lambs, short haul, direct

3 Biosecurity & Environmental Impacts

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Abstract

This review was commissioned to review literature concerning the impact of curfew (time off feed and water) prior to animal transport on environmental and biosecurity risks. The primary biosecurity risk identified was the dispersal of weeds during animal transport, especially from cattle from extensive grazing. Subsidiary risks include parasite and OJD spread. It was determined that a curfew less than 48 hours would have little, if any, mitigating impact on these risks. However from an environmental perspective, a 24 hour curfew (off-feed) would appear to significantly reduce the manure load released during transit. Reductions of 50% or more have been reported in studies of cattle fasted 24 hours. There are commensurate reductions in excretion of organic and nutrient contaminants, all of which pose environmental risks if spillage occurs in transit, especially in populated areas. There is only marginal additional benefit for longer curfew periods. Recommendations include further investigation of the impact of curfew for times less than 24 h, for sheep and goats and consideration of alternate strategies to minimise weed spread.

Executive summary

Environmental risk factors

Manure spilled during livestock transport is the principle environmental risk associated with livestock transport, especially in wet weather. Manure is offensive and highly polluting – even at low mass quantities. Very large mass loads of contaminants are associated with a single B-double vehicle load of animals (equivalent to sewage from a town of 250 persons). While it is unlikely that the entire manure load will be spilled (although this can not be discounted in wet weather), environmental risks include contamination of transport routes and environs with soluble organic matter, suspended solids, nutrients (nitrogen and phosphorus) and micro-organisms. On drying, this may generate contaminated dusts. In wet weather, it will generate contaminated runoff and wheel and slipstream sprays.

From an environmental protection viewpoint, the greatest environmental benefit is achieved by reducing the manure load excreted during transport, when it is at highest risk of escaping to the environment.

The literature suggests that very significant reductions in manure load (50% or more) and contaminant mass are achieved by a 24 hour curfew off feed for cattle. Curfews shorter than 24 hours may also be beneficial, but data are lacking, whereas longer curfews (up to 48 hour) have little additional benefit in reducing manure output. Curfew also appears to improve manure consistency, making it less susceptible to spillage. There are no equivalent studies for sheep or goats.

The beneficial impact of curfew is reduced for long-haul (greater than 8 hours) transport pathways when animals may need water and feed during travel to address animal welfare concerns.

Biosecurity Risk Factors

While the majority of livestock transport covers short distances (< 8 hours) relative to the size of the Australian continent, a significant amount of travel transports livestock from regions far distant to the final destination within Australia. This poses the risk of livestock transport acting as a conduit for the spread of noxious plants, animals and parasites.

The primary biosecurity risk is weed dispersal associated with transport of cattle off grazing properties. Studies show that hard seeds survive passage through ruminant digestive tracts better than soft seeds and all continue to be excreted several days after consumption. Sheep and goats are generally less likely to transmit viable seeds than pasture-fed cattle through a combination of higher mastication rates and preferential digestive processes. Feedlot cattle are probably also a lower risk as their feed is more stringently controlled than for extensively grazed animals.

Some WONS (weeds of national significance) are potential biosecurity risks during livestock transport. Studies have shown that their seeds can survive passage through cattle, and can be successfully spread by attachment to skin and hides of animals. Little is known about the effect of curfew on seed survival, however since peak seed excretion occurs for 2 – 4 days after ingestion, curfews of less than 48 hours are likely to be ineffective in preventing dispersion.

Similarly, curfews will have little or no beneficial effect in reducing dispersion of parasites. Expression of helminth eggs is not affected by short-term fasting, which is of insufficient duration to affect the animal’s immune system. It is therefore concluded that from a biosecurity perspective there is little if any benefit in curfew.

Recommendations are presented some identifying alternate strategies for minimising weed spread through livestock transport. Key areas where knowledge is lacking and would be useful in providing a more scientific basis for curfew benefits include the effect of short (24 h or less) curfews on manure loads from cattle and especially sheep & goats; assessing alternate strategies for minimising weed dispersal and the impact of weed seeds on hides and coats.

3.2 Introduction

3.2.1 Retention of Material in the Digestive Tract

3.2.1.1 Background

The load of digesta in the rumen begins to diminish as plant particles are reduced in size by rumination chewing and by fermentation, until they achieve a critical length and specific gravity consistent with their passage into the omasum. In doing so, they take with them any attached bacteria which join other microbes passing out of the rumen in the fine particle fraction of digesta.

Warner (1981) concluded that half-time is the appropriate measure for a specific seed type in the gut, and mean retention time applies to the whole digesta. The mean retention time of food in the gut varies both between and within species. Some experimentally determined mean retention times are summarised in Table 1.

Table 1. Mean retention times in the gut (Warner, 1981)

Animal	Mean retention time (h)
horse	26-37
grey kangaroo	38-45
goat	43
sheep	31-103
cattle	54-127

The results indicate that the mean retention time is greater in ruminants and larger animals, for example in cattle than in sheep. The work of Atkeson et al. (1934) supports these results, however Hecker & Grovum (1975) determined the residence time in the large intestine as approximately 19.7 h in sheep and in cattle 10.1 hours, The variation can be partially accounted for by the range within a species, due to differing age, condition, feeding patterns and feed composition.

Although mean retention rate can be determined, different sized particles will move at different rates through the gut with smaller particles generally moving through faster than larger ones (Warner, 1981). Seeds with the fastest rate of passage through the ruminant digestive system were either large and dense, or small and hard (Janzen, 1981; Gardener et al., 1993a).

The digesta does not move at the same rate in all sections of the gut, and some material can be delayed by being temporarily held in various sections. Examples include:

- Fluid and fine particles can spend on average 7-12 h in the rumen, compared to 12 – 48 h for larger particles.

- Particles can be trapped in the omasum for up to 2 h. The mean residence time in the abomasum is about 0.5 h, and in the small intestine 2.5 h (Warner and Stacey, 1965).

- The caecum selectively removes large solid objects from the digesta flow, returning them at intervals, and can account for the occasional retention of large seeds for a long time (Cooke, 2002).

It is therefore not uncommon for some food materials especially large seeds to be selectively retained for reasonably long periods of time. Heap & Honan (1993) reported the retention of *Reseda lutea* seeds by sheep for up to 12 days, and *Solanum elaeagnifolium* seeds for up to 31 days. Janzen (1981) determined that the large hard-coated seeds of the tree Enterolobium could be retained by horses for up to 60 days.

These characteristics of the digestive system, and their modification by curfew, impact on the usefulness of curfew for managing environmental and biosecurity risks associated with livestock transport.

3.3 Environmental risk factors

While a wide range of environmental factors are associated with animal transport including energy consumption and greenhouse gas production, odour and dusts, the primary environmental issue which is impacted by curfew is the production of manure in the transport vehicles. To some extent, several other environmental factors are linked to manure production and spillage including:

- Visual pollution deposited on roads and in some instances on other vehicles sharing the same roadway;
- Odours from spilled manure and the passage of the transport vehicles. The former is a more serious issue for affected residents, while the latter is more transitory.

This section will focus on the effect of curfew on manure spillage as the most critical issue.

3.3.1 Impacts from Manure Spillage & Disposal

3.3.1.1 Manure quantities

Fresh manure is the composite product of faeces and urine discharged by ruminants. Excretion of manure is the direct product of food consumption and is related to the size and type of the animal. Cattle normally defecate about 12 times per day, with a range of 11 to 16 recorded in different studies and a mean area of 0.07 m^2 each (range 0.06 – 0.09) (Phillips 1993).

Table 2 summarises manure production and its primary characteristics for a range of ruminants which are the focus of this study. The data are drawn from an American study (ASAE, 1990) and provide the most comprehensive data available. They should correlate reasonably well to Australian conditions and have been widely used in Australian Feedlot Manuals. Other sources typically quote cattle manure excretion of 5-6% of live weight per day with urine constituting 30% by mass of the manure. Fresh manure is usually sloppy (80 – 90% moisture content) and organic (volatile solids comprise 85% of total solids by mass). Fresh faeces (as distinct from manure) comprise 20 – 30% TS by mass, compared to fresh urine at 3 – 4.5% TS (Watt et al., 1994). Data for sheep are less readily sourced.

Table 2. Fresh manure & contaminant production on a daily basis (ASAE, 1990)

Parameter	**Units** *		**Mass on a per head basis**				
Animal			**Cattle**	**Cattle**	**Veal**	**Sheep**	**Goat**
Typical live weight			**640kg**	**360kg**	**91kg**	**40kg**[2]	**64kg**
Total fresh manure	kg	mean	55.0	20.9	5.6	1.6	2.6
		SD	10.9	6.1	2.2		0.55
Urine	kg	mean	16.6	6.5		0.60	
		SD	2.752	1.512			
Density	kg/m^3	mean	990	1000	1000	1000	1000
		SD	63	75		64	
Total Solids	kg	mean	7.7	3.1	0.47	0.44	0.83
		SD	1.79	0.94	0.19		0.06
Volatile Solids	kg	mean	6.4	2.592	0.21	0.37	
		SD	0.51	0.21	0.00		
BOD - 5day	kg	mean	1.02	0.58	0.15	0.05	
		SD	0.31	0.27	0.00	0.01	
COD/BOD ratio			6.9	4.9	3.1	9.2	
pH		mean	7.0	7.0	8.1		
		SD	0.45	0.34			
TKN	kg	mean	0.29	0.12	0.025	0.017	0.029
		SD	0.061	0.026	0.004	0.003	0.008
Ammonia-N	kg	mean	0.051	0.031	0.011		
Total-P	kg	mean	0.060	0.033	0.006	0.003	0.007
		SD	0.015	0.010	0.001	0.001	0.001
Potassium	kg	mean	0.186	0.076	0.025	0.013	0.020
		SD	0.060	0.022	0.009	0.003	0.009
Sodium	kg	mean	0.033	0.011	0.008	0.003	
Chloride	kg	mean	0.083			0.003	
Iron	mg	mean	7.7	2.8	0.030	0.32	
Manganese	mg	mean	1.22	0.43		0.056	
Boron	mg	mean	0.45	0.32		0.024	
Zinc	mg	mean	1.15	0.40	0.1183	0.064	
Copper	mg	mean	0.29	0.11	0.0044	0.009	
Total Coliforms[1]	cfu	mean	704	22.7		0.8	
		SD	1792	21.2			
Faecal Coliforms[1]	cfu	mean	10	10		1.8	
		SD	18	10			
Faecal Streptoccocus[1]	cfu	mean	59	11		2.5	
		SD	90	16			

Notes: All nutrient and metal values are given in elemental form. SD – standard deviation. Blank cells indicate absence of data.

[1]Mean bacteria colonies (cfu – colony forming units) per head multiplied by 10 e10.

[2]Adapted from 27kg sheep (ASAE data) to 40kg sheep (typical for Australia). Refer to original

ASAE tables for relevant standard deviations.

From an environmental risk viewpoint the key issues arising from the characteristics of manure relate to:

- The offensiveness of the manure to humans sensibilities;
- The high organic and nutrient content, both of which pose a serious threat to surface water bodies;
- The high microbial counts in manure;
- The ready solubility of many of the components in rainwater runoff, which increases the ability of contaminants to travel to vulnerable places distant from the original spillage.
- The formation of manure dusts.

3.3.1.2 Truckload Quantities

How environmentally significant is a truckload of manure? Table 3 presents our estimates of the mass of manure generated during a 6 hour journey per B-double livestock truck for three types of animals without curfew. The calculations for cattle are based on fresh manure data from NSW Ag. Dept (1990). Those for sheep and goats are derived from ASAE (1990) and are for fresh manure. Typical numbers of animals in a B-double were obtained from a large Australian abattoir livestock manager. This type of transport is most commonly used for large abattoirs (which process the bulk of Australia's kill).

Table 3. Estimated manure & contaminant load from a B-Double livestock transport (6 h basis)

Animal	**Live weight**	**Ave. no. in B-double**	**Mass of manure**		**Contaminant mass (kg/truck/6 h)**		
	(kg)		(kg/ head/day)	(kg/truck/6 hr)	BOD	TN	TP
Cattle	450	65	6.8	440	11.9	2.5	0.8
Sheep	40	650	0.4	260	7.8	2.7	0.6
yearlings	90	80	1.4	115	3.1	0.5	0.1

BOD – 5-day Biological Oxygen Demand; TN – Total Nitrogen; TP – Total Phosphorus.

There is a significant difference in impact between animals. A B-double vehicle transporting cattle will generate nearly twice the manure of the equivalent load of sheep and 4 times more than a load of yearlings. To put these figures in context, the cattle truck generates the contaminant load in manure equivalent of 250 persons in 24 hours. A large cattle abattoir may receive 15 – 25 trucks per day. Consequently the total daily manure load in transit represents the pollution equivalent of a small town.

3.3.2 Impact of Curfew on Manure Production and Characteristics

3.3.2.1 Manure & Contaminant Mass

Curfew leads to a significant and rapid (24 hrs) reduction in manure excretion.
A comprehensive and recent study of cattle by Gregory et al. (2000) in New Zealand show that the reduction in manure load per animal (faeces plus urine) fell from 7.17 kg (48 hour hay feed) and 5.77 kg (pasture fed) to only 1.70 kg for curfewed animals. This is a 70% reduction relative to pasture-fed animals. Their data are summarised in Table 4.

Table 4. Effect of pre-transport feed on cattle waste loadings during transport. (Gregory et al., 2000)

Parameter	48-h Hay	24-h Hay	24-h Pasture	24-h Fasted
Wet manure weight (kg/animal)	7.17	4.15	5.77	1.70
COD (g/animal)	598	441	418	191
TN (g/animal)	14.6	13.1	17.7	12.4
TP (g/animal)	2.92	1.92	1.94	0.98

Quantities measured in truck after a 2 hour transport period; cattle had access to water for all treatments.

Similar results have been reported for yearlings. During a 48 hour fast of steers, 70% of the faeces were excreted in the first 24 hours (Cole et al., 1986), and by the end of the fast rumination has virtually ceased. The results were explained as the retardation of fermentation when feed is withheld from livestock.

Gregory et al. (2000) determined that fasting (feed only) animals before transport favoured the formation of a high pH-low dry matter rumen environment as the rate of volatile fatty acids (VFA) production declines. The rumen pH increases to 7 or above because of the reduction of volatile fatty acids (Warner and Stacey, 1965), and at the same time the quantity of digesta in the intestines is also gradually reduced. As the rumen empties, there is a slowing of digesta passage through the large intestine and the discharge of faeces will also decline.

Work done by Bass & Dugananzich (1980) provides time series data which shows the effect of time of fasting on intestinal and stomach content mass over 48 hours (Table 5). They show that within 24 hours curfew, intestinal load has fallen 50% and stomach contents by 24% for 450 kg live weight cattle. Table 6 shows that much of the reduction occurs in the first 17 hours (and perhaps even earlier). Curfew for a further 24 hours (until 48 hr total) achieves only relatively minor additional reduction.

There is very limited information on the impact of fasting on the actual volume and composition of manure from animals other than cattle. However the pellet nature of sheep and goat manure suggest that it may be less susceptible to spillage and the truckload quantities are much less than for cattle.

The digestibility of the feed will affect the load in the digesta. Increased digestibility (for example feeding young plants) will cause more rapid digestion and fermentation, thereby reducing the load in the digesta. By comparison, the reduced digestibility of more mature feed will cause a correspondingly higher manure load (Weston, 1985). By inference, a feed with high seed loadings, which is more mature, will probably remain for longer in the digesta. Animals feed highly digestible feed – for example feedlot cattle – should therefore produce less manure on a comparable body weight basis. However, feedlot animals will be heavier than extensive pasture-fed animals and the difference in manure load per head may be small.

Reductions in contaminant (COD, nutrients) mass excretion were significant in curfewed animals (Table 4), but less so than manure mass – probably due to the fact that curfewed manure was wetter (Gregory et al., 2000). Whereas mass loads of COD and total phosphorus in curfewed cattle were markedly reduced in comparison to pasture, or fed cattle, the reductions were less significant for nitrogen – possibly due to ammonia in urine.

3.3.2.2 Manure Characteristics

Curfew has a pronounced influence on the consistency of manure. When cattle are fasted before transport, the weight of gut contents decreases (as noted above), but the material usually becomes more liquid (Bass and Duganzich 1980). These authors noted that the moisture content of stomach contents increased from 86.2% at time zero to 93.4% after 48 hours (Table 5). Consequently the dry matter in the digesta decreases both absolutely and as a percentage of the total contents. Cole et al (1986) similarly observed that transport of yearling steers increased losses of water in faeces and urine following a 46 hour fast.

Intriguingly however, Gregory et al (2000) determined that even though curfewed cattle usually have a moister digesta (the runniest rumen contents), the cattle that were fed – and especially on pasture - up to the time of trucking distributed their faeces over a larger area on the basis of a comparative 'splatter test'. This was attributed to higher levels of stress in non-curfewed animals. A previous study of bulls showed that if cattle were transported in a fed state, they are more likely to be stressed (Jacobsen and Cook 1997), resulting in runny faeces. The faeces from pasture-fed cattle also contained a higher proportion of the sludge phase relative to the fibre and free-water phases. The combination of runnier and higher sludge phase faeces is thought responsible for the higher levels of fresh faecal soiling on the hide in "full" pasture-fed animals. Consequently feed from pasture or hay for 48 hours up to the time of transport has an adverse effect on cattle faeces consistency and stock cleanliness. A 24 hour curfew before transport is the most beneficial in reducing poor consistency manure

Table 5. Effects of starvation on contents of bovine alimentary tract. (Bass & Duganzich, 1980)

Parameter	**Starvation Time (hours)**				
	0	17	24	41	48
Body weight (kg)	465	487	487	478	476
Fasted live weight (kg)	476	441	435	430	426
Hot carcass weight (kg)	260	250	252	251	245
Stomach contents (kg)					
- Total	54.7	39.7	41.7	37.6	39.1
- Dry Matter	7.6	4.5	4.2	2.8	2.7
- % Dry Matter	13.8	11.5	9.9	7.0	6.6
Intestinal contents (kg)	10.5	9.0	5.3	5.5	4.7

From table 5 the change in quantity in the mass of intestinal contents can be assessed as a mass balance over a period of time where:

mass out (excretion) = mass (initial - final) in intestine + mass(initial – final) from stomach – mass absorbed through intestinal walls

If it assumed that absorption through the intestinal walls is essentially constant (and assessed here at zero), then approximate figures for excretion over a period of time can be calculated (Table 6).

Table 6. Rate of excretion with time of fasting

Time period	Mass excreted
0 – 17 hrs	16.5
17 – 24 hrs	3.7
24 – 41 hrs	3.9
41 – 48 hrs	0

These results suggest that voidage may occur preferentially early in a 24-hour curfew suggesting that a curfew time less than 24 hours may provide a disproportionate benefit in reducing manure load during transport. However, further work is needed to determine whether this actually occurs.

3.3.2.3 Summary

- Manure spilled during livestock transport is highly polluting.
- Very large mass loads of contaminants are associated with a single B-double load of animals – especially cattle.
- From an environmental protection viewpoint, the greatest environmental benefit is achieved by reducing the manure load excreted during transport, when it is at highest risk of escaping to the environment.
- The literature suggests that very significant reductions in manure load (50% or more) and contaminant mass are achieved by a 24 hour curfew off feed and water. Longer periods have less incremental benefit.
- Curfews shorter than 24 hours may also be beneficial, but data are lacking.
- Curfew also appears to improve manure consistency, making it less susceptible to spillage.

3.4 Biosecurity Risk Factors

While the majority of livestock transport covers short distances (< 8 hours) relative to the size of the Australian continent, a significant amount of travel transports livestock from regions far distant to the final destination within Australia. This poses the risk of livestock transport acting as a conduit for the spread of noxious plants, animals and parasites.

This section reviews knowledge of the influence of curfew on biosecurity risks. Those risks potentially susceptible to curfew include:

- Spread of noxious weeds;
- Spread of parasites – both animal and zoonotic.

3.4.1 Weed Seed dispersal

Curfews will only have impact on weed seed dispersal where either the viability of the seeds is significantly reduced during the curfew period, or excretion of the seeds is prevented during transport, or accelerated within the curfew period.

The previous section identified that curfew of the order of 24 hours significantly reduces the mass of manure excreted during transport. However the passage of seeds eaten previous to curfew may not be affected. This section explores the effect of curfew on seed viability and excretion.

3.4.1.1 Passage and viability of seeds in faeces

Influence of seed type

The survival of legume seeds was largely dependant on the fraction of hard or impermeable seed in the sample, both in the animal and after excretion in the faeces. Gardener et al (1993a and b) investigated the survival of seeds from a range of 10 legume and 8 grass species found in tropical and sub-tropical pastures. The seeds were placed directly into the rumen of cattle, and their passage and survival tracked over a 160 hour period. More legume seeds than grass seeds survived the passage, but there was a marked variation between species, both in grasses (0 – 64%) and legumes (0 – 78%).

Hardness of legume seeds was an easy and reliable indicator of resistance of the seed to digestion. Hard seeds were still being excreted when the experiment finished (after 160 h). Soft seeds, by comparison, swelled and ruptured in the rumen within 6 hours. This is supported by the work of Simao and Jones (1987), whose study on the impact of soft and hard seed on digestibility and viability determined that soft seeds were destroyed by digestion treatments (microbial activity in the rumen and digestive enzymes and acid in the stomach) whereas hard seeds were largely resistant to digestion.

Influence of animal type

Numerous studies indicate that cattle pose the highest risk of seed spread among ruminants. Simao et al (1987) investigated the effect of different species of ruminants and pasture plants on the passage of ingested seeds. Studies from cattle, sheep and goats indicated that cattle digested less seed than sheep or goats, as assessed by the larger number of hard seed in cattle faeces, but the viability of recovered seed was the same for all animals.

The rate of passage of annual ryegrass (*Lolium rigidum*) through cattle and sheep was studied by Stanton et al (2002) who determined that the seed was present in the faeces of both sheep and cattle within 24 hours of first digestion, with 10.8% and 32.4% of the seed ingested being excreted by sheep and cattle respectively. The percentage of viable excreted seeds was only 3.9% and 11.9%, respectively. Seeds continued to be excreted by both sheep and cattle for up to 5 days after removal from the diet. The authors concluded that there is considerable potential for dissemination of hard-seeded legumes (eg Stylosanthes) by cattle, but not tall tussock grasses. Older studies such as Atkeson et al. (1934) and Harmon & Keim (1934) recorded that the percentage germination of over 20 weed species decreased with time in the gut. Seeds of *Pennisetum clandestinum*, consumed heavily by cattle, survived better than seeds of tall tussock grasses which are rarely eaten.

Sheep do not spread the seed as effectively as cattle, and graze seedlings more heavily (Stanton et al, 2002). The majority of canola seed was found to pass through wethers in the first two days with seed germinability being reduced after one day, and further still after 2 days, but not significantly after that time. A 7 to 10 day holding period was suggested to ensure weeds are not inadvertently spread outside the paddock. Jacobsohn et al (1987) placed seed of various Orobanche (branched broomrape) species in the rumen of rams. Most viable seeds were excreted after the second day, with none being recovered after the fourth day. In two other case studies of seeds ingested by sheep, *Echium plantagineum* seed was mostly passed within 3 days (Piggin, 1978), although none of these were viable. Cook (1998) determined that recovery of *Nassella trichotoma* seeds peaked on days 3 and 4 and had fallen to a low level by day 7. Viability was low.

Andrews (1995) collected from 14-52 viable seeds per kg faeces from cattle which had been fed on a paddocks infested by giant Parramatta grass (*Sporobolus indicus var.major*). All seeds were excreted in a period from 4 to 7 days after consumption. However, the highest concentration of viable seeds was found in manure collected 2 and 3 days after feeding. They determined that processes that disperse fresh manure, such as heavy rain or hosing down of transport vehicles may allow for successful germination of the seeds.

In summary it appears that the great majority of seeds are passed by the fourth day, but occasional seeds may lag for an indefinite time. Of the seeds that are passed, soft seeds are least likely to be viable, whereas hard seeds are more likely to withstand the digestion process. Cattle are more likely to pass higher numbers of viable seeds than other animals.

3.4.1.2 Survival of seeds in faeces – WONS

<u>There is a high risk of cattle from extensive pastures spreading noxious plant species</u>. There are 20 weeds of national significance (WONS), with the agreed methodology for selection based on the following four major criteria:

- invasiveness,
- impacts,
- potential for spread,
- and socioeconomic and environmental values.

There are certain key WONS that are particularly significant in terms of animal transfer, primarily through faecal distribution (http://www.weeds.org.au/natsig.htm). These include:

- Prickly acacia (*Acacia nilotica ssp. indica*)
- Mesquite (*Prosopis* spp.)
- Chilean needle grass (*Nessella neesiana*)

Prickly Acacia's long distance spread in Australia is mainly attributed to consumption of seeds by cattle, which readily eat the nutritious, ripe seed pods. At least 40% of the seeds consumed in this way are viable after being excreted, which is normally up to six days after consumption. Manure assists germination by providing extra moisture and nutrients. Cattle spread viable seeds more effectively than either goats or sheep, which tend to chew the seeds.

Mesquite is also spread by animals that consume the seed pods and excrete viable seed droppings. The digestive process also appears to help germination, provided the seeds are not damaged by chewing. Cattle are mostly responsible for its spread.

Seeds of Giants rats' tail grass, an unpalatable and aggressive pasture weed were fed to cattle in a controlled experiment that determined 41% was excreted, with 79% remaining viable. Most of the seed (94%) was excreted on days 2 and 3, with none being detected on day 4 (Bray et al., 1996).

Other weeds are more vulnerable. Few seeds of Chilean needle grass survived passage through the gut of Angus steers and all viable seeds had passed in 4 days (Gardener et al, 2003a).

3.4.1.3 Potential impact of fasting on survival of seeds

Little is known regarding the impact of curfew on weed seed survival. Jones and Simao (1987) studied the effect of feed digestibility on seed survival in sheep. Penned sheep were fed a low (45%) digestibility diet in comparison to medium (60%) and high (70%) diets supplemented with a range of seeds. Only 10% of ingested seed was recovered from the low quality diet, compared to 28% from medium and high quality diets. Furthermore less Seca seed was still in the pods with the low quality diet than with the medium and high quality (6% as compared to 11%). It could therefore be deduced that fasting encouraged the digestion of seeds that would not normally be preferentially digested.

With fasting it is presumed that two counteractive processes will occur. As the animals are removed from feed they will start to excrete seeds, with this peaking during the first 2 days after the feed has been removed, reducing after 3 – 4 days. Due to the restricted food intake, they will also be digesting seed that may not normally be digested. However as the rumen becomes less acid, and the rumination slows with fasting, it is presumed that the digestion of soft seeds will slow accordingly, and any seeds in the rumen may have a greater chance of survival. However as many soft seeds swell and rupture within the first 6 hours, there is likely to be less impact from the changed internal conditions.

3.4.1.4 Transfer of seed on coat and hoof.

Weed seed dispersion can also result from attachment of seeds to animal hides and skins. The attached seeds are then dislodged during transport. Little has been reported on seed survival and dispersion time constants associated with the transfer of seed on the coats and hooves of animals, or the impact of curfew. Gardener et al (2003) determined that the half life of Chilean needle grass seeds in sheep's wool was 7.5 days, although 25% were still present after 5 months. Bray et al (1996) indicate that the seed of Giant Rats Tail becomes sticky when wet and attaches to animals, falling off when drying, after periods of time ranging from hours to days.

3.4.1.5 Summary

- Hard seeds survive passage through ruminant digestive tracts better than soft seeds. Seeds continue to be excreted several days after consumption, with peak excretion after 3 - 4 days.

- Cattle appear to be less effective in destroying seed viability than either sheep or goats.

- Some WONS are potential biosecurity risks during livestock transport. Studies have shown that their seeds can survive passage through cattle and may be successfully spread by attachment to skin and hides of animals.

- Little is known about the effect of curfew on seed survival. However, since peak seed excretion occurs for 2 – 4 days after ingestion, curfews of less than 48 hours are likely to be ineffective in preventing dispersion.

3.4.2 Parasite Dispersal

The excretion of parasitic eggs and larvae during transport poses a biosecurity risk only where spillage of manure results in large numbers of parasites being liberated to pastures or watercourses adjacent to transport routes and which are accessed by animals. This is unlikely during dry weather since the dispersed nature of the spillage, high levels of irradiation and the heat from the road surface will typically kill parasitic eggs and larvae rapidly. A more significant risk presents during wet weather, when high volumes of contaminated runoff can enter watercourses and low lying pasture and initiate infection of resident ruminants or hosts.

3.4.2.1 Parasites of concern

There are a range of parasites that affect the key livestock species in Australia (MLA 2005; Boray 1999, Wormboss, 2004).

- ***Small brown stomach worm (Ostertagia spp)***
  This is present in all herds, especially in the temperate areas of southern Australia. It is most prevalent in young animals, since by 18 months most cattle have developed immunity to it. It is also an issue in sheep, potentially invading the wall of the sheep's fourth stomach causing scouring, weight loss and even death. As some larvae can survive in faeces, emerging when rain ‘melts’ the pats during cooler weather, it is conceivable that these parasites could be transferred by faecal contamination of transport routes. Owing to the endemic nature of this worm, however, there is probably not a high risk that this would cause an introduction to an uncontaminated site.

- ***Liver and stomach fluke (Fasciola hepatica)***
  Over 6 million cattle graze pastures at risk of liver fluke infection, a parasite that can also infect a wide range of domestic livestock and native grazing animals. The adult fluke, which lives in the liver, may produce up to 50,000 eggs per day. These are passed via bile to the intestinal tract and then to faeces and hence to pasture. The eggs will hatch from 20 to 90 days, depending on the temperature. However the resultant immature liver fluke requires a specific host snail within a short time span (3 hours) of hatching in order to survive. The main host is *Pseudosuccinea tomentose*, a hardy snail that can survive for log periods in dry mud, but thrives in shallow watercourses, marshland and irrigated areas. Liver fluke is present in all states, but most risk is centred on south eastern states where the habitat is suitable for the snails.

  On any property there may be only small areas that are affected because of the specific requirements of the snails. It is therefore presumed that the requirement for infection and proliferation of liver fluke is more dependent on appropriate local conditions than on the introduction by animals in transit. Humans may be impacted by liver fluke, but only by consuming plants that are grown in an environment suitable for snail proliferation such as unwashed watercress. There is no direct transmission from animal manure to humans.

- ***Black scours (coccidia)***
  Coccidiodsis is a disease caused by protozoa (Elmeria), which primarily affects young calves. It occurs in all areas in Australia, primarily in warm wet areas. Most animals will be infected with this parasite at some stage, and the majority recover with a strong immunity to it. However the preponderance of oocysts in contaminated calves can cause localised outbreaks in areas such as watering holes or weaning yards where they are in contact with other calves. Although the

oocysts can survive for long periods, they are unlikely to cause problems from manure of animals in transit.

- ***Barber's pole worm (Haemonchus contortus)***

This parasite, present in cattle and sheep, feeds on blood from the wall of the fourth stomach. Heavy infections cause sudden death from massive blood loss. Most infections cause weakness, poor productivity, anaemia and bottle jawblack. It is most common in areas of summer rainfall, such as in all sheep production districts in Queensland and the northern half of NSW. The adult female in the 4th stomach (abomasum) lays up to 10,000 eggs per day, which are passed out in the faeces. The larvae feed on bacteria in the dung pellet until they either die or escape onto pastures following rain or heavy dew. They then migrate up the grass blades in the warmth of the sun, where they are eaten, and the cycle starts again. Although it is possible that this parasite can be transferred by animals in transit, there is no evidence that curfewing before transit would be effective.

- ***Scour worm (Trichostrongylus colubriformas***)

Black scour worms occur in all sheep production districts of Australia, and burrow into the wall of the stomach and small intestine causing scouring, loss of appetite and condition, weakness, dehydration and death. Their life-cycle outside the sheep is similar to the barber's pole worm.

3.4.2.2 Effect of curfew on parasite survival

There is little recorded regarding the effect of curfew on parasite excretion. Certain authors (Barret et al, 1998, Sanchez et al, 2000) recommend curfews prior to and following drenching, however this is more to ensure that the treatment itself is effective, rather than to directly influence the viability of the parasites. Curfews have been found to be advantageous in this context since passage through the stomach is slowed, resulting in greater uptake of the drench by the host.

The current view is there would be very little, if any effect of short curfews on the expulsion of worm eggs from livestock (Bessier, 2006). Worm loads in faeces are mediated by the immune system of the animal. There is clear evidence that nutritional inadequacies, especially of protein, can reduce the rate of acquisition and subsequent expression of immuno-competence against parasitic infection (Bessier, 2004), as seen by the positive effect of high-protein diets. However, although the rate of expulsion increases if the internal immune environment is hostile, and a situation potentially caused by an extended restricted diet could compromise the resistance of livestock, there is no evidence that the limited fast of a curfew would impact on the load of eggs expressed.

Studies have shown that curfew reduces manure load excreted by the animal. Unfortunately, the load of eggs excreted by infected animals is largely constant for a given immune state and unaffected by the feed quantity or type. Consequently, if the mass of faeces is reduced, the egg count will be more concentrated.

3.4.2.3 Johne's disease (JD) in Sheep, Cattle and Goats

JD is an incurable disease caused by *Mycobacterium* bacteria infecting sheep, cattle and goats (cattle and sheep with separate strains; goats with both strains). The disease in sheep was first discovered in 1980, areas where the disease is most prevalent is mainly in SE NSW but has more recently been discovered in the West of

Australia. A large control program is underway to control the disease and a vaccine is available.

Faeces and contaminated run-off are known to spread JD between farms. One study has detected the organism in the intestinal lymph nodes or faeces of 34% of 189 healthy thin dairy cows and from 3% of 350 healthy thin beef cows at slaughter (Rossiter & Henning 2001). It is possible that water sources may be contaminated through the excreta of infected animals (ruminant and non-ruminant). Water running off from grazing lands, or lands that have used manure from infected animals as fertiliser, may therefore contain viable organisms (Whan et al 2001). Animals in transit are therefore equally likely to transmit infection through manure deposited on the roadside and surrounding areas. It is not apparent, however, that a curfew would have any beneficial effect on the reduction of transmission since zero extra excreta expulsion is not achievable. In contrast, levels of some bacteria, such as *E. coli*, increase following fasting, and there could be the possibility that a similar phenomena occurs for the bacteria responsible for JD.

Controlled transport of sheep (especially) from the at-risk areas would appear to be a superior means of minimising this risk.

3.4.2.4 Summary

- Short curfews typically used at current will have little or no beneficial effect in reducing dispersion of parasites.
- The risk of parasite dispersion during livestock transport is likely to be significantly higher during wet weather. During hot, dry weather, rapid die off rates make dispersion of viable, infective eggs a low risk.

3.5 Conclusions and Recommendations

3.5.1 Biosecurity

1. From a biosecurity perspective there is little if any benefit in curfew.

2. Cattle are most likely to contribute to the transfer of viable seeds through their elimination in faeces. They are seen as important in the spread of some WONS.

3. The seeds that are likely to create a biosecurity hazard are primarily those that are hard and slower to digest. These seeds can be held in the stomach for up to 3 days before expulsion, with primary excretion on days 2 and 3. Consequently, short curfew periods (e.g. 24 hours) would not allow sufficient time for significant numbers of seeds to be expelled prior to transit.

4. Feedlot cattle are assessed as a lower biosecurity risk in regard to weed spread as their feed is more stringently controlled than for extensively grazed animals.

5. Sheep and goats are generally less likely to transmit viable seeds through a combination of higher mastication rates and preferential digestive processes.

6. Curfew will have little if any impact on the rate of excretion of helminth eggs. Expression of worm eggs is not affected by short-term fasting, which is of insufficient duration to affect the animal's immune system.

7. As the elevated shedding of some pathogens occurs under stresses associated with curfew and transport activities and the shed parasite load is independent of volume, curfew may in fact increase discharge of parasite egg and microorganism loads.

3.5.2 Environmental

1. Environmental risks include contamination of transport routes and environs with organic matter, suspended solids, nutrients (nitrogen and phosphorus) and microorganisms. On drying, this will generate contaminated dusts. In wet weather, it will generate contaminated runoff and wheel and slipstream sprays.

2. A curfew prior to animal transport can be expected to very significantly reduce potential environmental impact. The primary benefit is a marked reduction (approx. 50%) in the mass of faeces and urine excreted. The predicted decrease in faecal volume would be beneficial both from the reduced faecal load in the truck and reduced risk of contaminant transfer to roads and surrounding areas. This is of particular significance during transit through built-up areas, particularly in wet weather.

3. The beneficial impact of curfew is reduced for long-haul (greater than 8 hours) transport pathways when animals may need water and feed during travel to address animal welfare concerns.

3.5.3 Recommendations

1. A 24 hour curfew off feed and water would decrease the mass of faeces and urine excreted; resulting in significant reductions in the loads of nutrients, organic waste, and micro-organisms discharged to the Australian environment and reduced visual pollution.

2. Distribution of weed seeds by animals in transit is recognized as a biosecurity issue. Short duration (up to 48 h) curfews are ineffective in minimising seed excretion. Alternate, and more effective, options for decreasing risks associated with seed transmission might include:

    - Quarantining cattle from farms where access to weeds has been uncontrolled. A minimum period of 3 days quarantine prior to transport, with grazing and/or feeding on high quality, weed-free fodder, would allow time for the bulk of the hard, digestion-resistant weed seeds to be excreted. Quarantine paddocks would need upkeep to prevent weed seed germination and growth.

    - Pasturing animals on land that has been specifically selected as free of weeds that have been specifically identified as likely to be transmitted by animals in transit. These include weeds of national significance such as prickly acacia, mesquite and giant rat's tail.

3. Investigation of different curfew and transport strategies for young ruminants which are known to contribute disproportionately to shedding of pathogens and (possibly) parasite eggs.

3.5.4 Future investigation

There are several areas where unambiguous knowledge is lacking. These include,

- the impact of fasting on the weight and composition of manure from animals other than cattle (especially sheep), although their total environmental impact is probably less than for cattle.

- the rate of reduction of the key indicators in faeces (weight, COD, TN, TP) with short duration curfews (less than 16 hours), in order to determine optimum times.

- determination of times associated with release of seeds attached to hides and coats after livestock have been removed from weed-infested areas.

- Assessing the effectiveness of alternate strategies for minimising weed seed dispersion under Australian conditions.

- Assessing the effects of off-water (up to 24hours) on manure and urine quantities from both cattle and sheep.

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4 Meat Quality - Beef

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Executive summary

Carcass yield losses will be reduced by minimising the time animals are off feed and/or water.

- Aggravating conditions surrounding the time off feed and/or water can increase the risk of poor meat quality and/or reduced carcass yield. Animals are more bullet-proof to aggravating conditions with better nutrition pre-transport.
- Curfew on-farm has to be conducive to rest.
- Guidelines provided by MSA for reducing dark-cutting, selling cattle through a saleyard and for handling cattle should be followed to minimise the impact of time off feed and water on carcass yield and meat quality. The total allowable time between dispatch and slaughter is 36 hours with access to water in curfew and lairage.
- Cattle kept off water between farm and slaughter and not given an opportunity to rehydrate will produce lower carcass yields. Cattle off water for as short as 12h prior to slaughter have lower carcass yields thus it is recommended that access to water is provided at all times. Given access to water, cattle will rehydrate fairly quickly although it is not clear how long they need access to water to allow sufficient rehydration to eliminate carcass yield differences. The issue that needs attention is the availability and size of water troughs at saleyards and abattoirs and the quality of the water.
- Cattle kept off feed will start to catabolise their fat and muscle tissue after 1-3 days and this will reduce carcass yield. Feeding is recommended for cattle in transit for longer then 2-3 days. The challenge with feeding cattle in spell paddocks or lairage pens at the abattoir or at saleyards is the quality of the feed and whether the cattle are settling down and eating properly, or actually still catabolising body tissue. For this reason the recommendation is that the total time from farm to slaughter is always kept as short as possible. It is recommended that the possibility of a high quality tailored diet is investigated for cattle at risk. This could be an on-farm pre-transport supplement or for feeding at abattoirs. Provision of a specialised feed is not intended to allow the time from mustering and slaughter to be extended but to improve the carcass yield and meat quality of cattle at risk.
- The time between mustering and slaughter has a greater effect on losses in carcase weight then either distance travelled or transportation alone. When this interval exceeds 3 days, there are serious losses in carcase weight. For cattle which necessarily travel long distances at certain times of the year, the ideal rest/feed period and conditions is not clear and requires clarification.
- Bruising on beef carcasses reduces carcass yield. There is no direct evidence for time off feed and water influencing carcass bruising but there are a multitude of risk factors between farm and slaughter for carcass bruising. The known risk factors include long transport, high and low stocking densities in transport, mixing unfamiliar cattle, saleyard selling, noisy (not ‘restful’) lairage yards and chronic stress.
- During the period between farm and slaughter, there is limited evidence that time off feed and water have an influence on meat quality *per se*. For example long transport, saleyard selling and lairage beyond 2 days can all

increase the incidence of dark-cutters and all involve elements of time off feed and/or water. But there is ample evidence that the conditions under which the time off feed or water are applied can detrimentally affect meat quality, in particular the incidence of dark-cutting beef carcasses. The risk factors include those given for bruising as well as exposure to cold and changing seasonal conditions. Thus attention must be concentrated on ensuring that the conditions of mustering, penning on the farm, loading, transport (including stocking density, duration, road type), unloading, saleyard management (where applicable) and abattoir lairage (stocking density, provision of quality feed and water, duration, flooring, 'restfulness'), are optimised. An example of this is that the 'lairage' pens at abattoirs are supposedly where the cattle rest and recuperate. But if the pens are not conducive to rest, the longer the period spent in lairage (off feed, with variable access to water) the greater the detrimental impact on both the carcass yield and the meat quality.

4.2 Definition of meat quality

Meat quality is defined as the traits which are; (a) appealing to the eye when the consumer views the meat prior to purchasing and (b) appealing to the palate when the consumer eats the meat. Thus meat colour is a visual quality trait which the consumer uses to judge the quality and important palatability traits are tenderness, juiciness, chewiness and flavour. The main meat quality defect that may manifest as a result of stress between farm and slaughter is "dark-cutting" high ultimate pH meat. Dark-cutting meat is a direct consequence of low muscle glycogen levels at slaughter. Dark-cutting meat is dark and therefore less acceptable to the consumer, with variable tenderness, reduced shelf-life and bland flavour.

4.3 Definition of Carcass yield, including bruising

The carcass is the part remaining after bleeding, skinning, evisceration and other normal dressing procedures. The carcass is composed mainly of muscle, fat and bone, and losses of tissue substance or moisture from any of these components will reduce carcass weight. Bone is relatively unaffected by the normally short duration of marketing procedures. The major weight losses arise from dehydration of muscle and fat tissues when water is withheld, and catabolism of muscle and fat tissue when feed is withheld, since cattle then have to draw on their body tissue to supply their water and energy needs.

When an animal is injured, blood vessels are ruptured and blood infiltrates the surrounding tissue, causing a bruise. This tissue is usually trimmed before the carcass leaves the slaughter floor, directly reducing carcass weight and therefore carcass yield. Carcasses may also be downgraded due to bruising. It is obvious that bruising is a cost to industry as well as being an indication of compromised welfare of the animal. Thus bruising has been included in this section when time off feed or water have been found to impact on bruising levels in carcasses. The potential role of time off feed and water in determining carcass bruising is predicated on two assumptions. The first assumption is that as previously shown by (Barnett, Eldridge, McCausland, Caple, Truscott & Hollier, 1984), chronically stressed cattle have a higher propensity to bruise. The second assumption is that it will tend to be the conditions under which the time of feed and water are imposed that will determine the bruising on the carcass.

4.4 Detrimental effects of curfew in combination with total time off feed and water (adding in transport & lairage) on weight loss of cattle and carcase yield

Animals being moved from farm to slaughter in Australia are not usually fed (ie. they are fasted). Fasting depresses water intake so the hydration status of animals is also affected (Shorthose and Wythes, 1988). Time, off water and/or feed, has the greatest effect on both live and carcass weight loss. The rate decreases exponentially for liveweight and linearly for carcass weight (up to 4 days) (Shorthose and Wythes, 1988).

Hydration status probably affects carcass weight more often, and to a greater degree, then tissue catabolism ((Wythes & Shorthose, 1984). Cattle denied water for 2.5 days have 3.8% lighter carcasses then those offered water ((Wythes, Shorthose, Schmidt & Davis, 1980a)). It is possible that after a period of dehydration, animals may temporarily overhydrate ((Wythes et al., 1980a);(Wythes & Brown, 1983)).

The available evidence suggests that catabolism does not reduce carcass weights until cattle have been without feed for about 24 hrs ((Wythes et al., 1984). Thereafter, the extent of the losses depends on whether or not cattle are continuously or intermittently denied feed. In the USA, carcass weight is thought to be affected only after 3 days of fasting (Kirton et al., 1972; cited in Warner et al., 1986) but this may be due to grain-fed cattle being different to grass-fed cattle. Early work (Shorthose, 1965), suggest that when cattle are without feed and water for 4 days, they lose about 0.75% of on-farm carcass weight each day. Other Australian studies have shown that cows and bullocks which were fed and watered occasionally over a 3-11 day marketing period lost between 0.3 and 0.5% per day ((Wythes, Arthur, Thompson, Williams & Bond, 1981); see Figure 2).

4.4.1 Effects of On-Farm conditions on Carcass Yield

Pre-transport fasting has been found to increase bruising (Dodt et al., 1979; cited in Shorthose and Wythes, 1988) or have no effect (Bond et al., 1981; cited in Shorthose and Wythes, 1988).

4.4.1.1 Effects of Transport (as an Imposed Time off Feed and Water) on Carcass Yield

It is debatable whether transport *per se* increases liveweight or carcass weight loss, relative to that which occurs in animals deprived of feed and water for similar times (Shorthose and Wythes, 1988). Transport (1880 km) does not appear to reduce the carcass weight more then that which occurred when cattle were subject to similar feed and water deprivation *in situ* (Holmes et al, 1982; cited in Shorthose and Wythes, 1988) although this is not the case for calves (Phillips et al., 1985; cited in Shorthose and Wythes, 1988).

In two separate studies (Wythes et al., 1981) demonstrated that cows transported for 2055 or 870 km had a higher bruise score (equates to 0.6 kg bruise trim per carcase) than cows transported for 460 km, even though the total time from farm to slaughter (8 days) and the time on feed and water was standardised. In one of the studies, the cows transported for 400 km had a higher carcase weight then those transported for 870 or 2055 km. They concluded that substantial losses in carcase weight occurred after the cows were transported more then 460 km and three to four days elapsed between mustering and slaughter. Such losses were attributed to catabolism of tissues. Bullocks are not reported to have an increase in bruising with distance travelled (Dodt et al., 1979; cited by (Wythes et al., 1981)).

4.4.1.2 Effects of Saleyards (as an Imposed Time off Feed and Water) on Carcass Yield

Cattle sold through saleyards for slaughter are generally in transit from farm to abattoir longer then cattle sold directly to the abattoir. Cattle marketed through saleyards for slaughter are also subjected to more handling, are in transit and without feed and water for longer and are exposed to more potential stressors (Warner et al., 1998).

Cattle transported for 1300 km by rail without feed, water or rests achieved the greatest increase in liveweight (having lost 14.3%) when given access to both feed and water during the pre-curfew period and access to water during the 12h curfew and 9 h sale (Wythes et al, 1981). This was in comparison to cattle given only water throughout, water only during the pre-curfew period or no water throughout (Wythes et al., 1981) (see Figure 1).

Warner et al (1988) showed that cattle going through a simulated saleyard procedure had higher bruise scores and a tendency for lower carcass weight then cattle going direct to the abattoir.

4.4.1.3 Effects of lairage (as an imposed time off feed and water) on Carcass Yield

The amount of feed which cattle will eat at abattoirs depends on how long they have fasted and on whether they are accustomed to trough/floor feeding (Wythes et al., 1984). They are unlikely to eat as much as they would while grazing. Certainly feeding hay at the abattoir can reduce losses in carcass weight when cattle are held for several days at an abattoir before slaughter ((Wythes, Smith, Arthur & Round, 1984)). The ideal scenario is to minimise the period spent at the abattoir as it extends the time between farm and slaughter. But when cattle do need to spend longer periods (eg. 2 days or more) at the abattoir, it is necessary to offer good quality feed to minimise the impact on both carcass weight and meat quality.

The carcass yield of cattle kept in lairage for 18 hr or 3 hrs on water, but no feed, was found to very similar (Ferguson et al., 2006b).

Eldridge et al (1988) videoed cattle in lairage pens at an abattoir and found that cattle in pens next to the unloading ramps were more unsettled and agitated and had higher bruise scores.

4.4.1.4 Effects of Total time off feed and/or water on carcass yield

Although resting and feeding and watering cattle en route to slaughter reduces carcass weight loss somewhat (12.1 v. 13.1%, van den Heever et al., 1967; 4.2 v. 5.8%, Young, 1973; as cited in Shorthose and Wythes, 1988) as did providing water and feed in transit (Young, 1973; as cited in Shorthose and Wythes, 1988) or during lairage at the abattoir (Wythes and Shorthose, 1984), they did not prevent it.

In Canada, cattle fasted for 24h with access to water and slaughtered had a heavier carcass weight relative to cattle fasted for 48 h (including 320 km transport) or 72 h (including 320 km x 2 transport on separate days) with access to water (Jones et al., 1988).

Cattle off water for 12 h have elevated serum chloride and reduced muscle chloride as well as highly elevated urine osmolality, indicating dehydration resulting in a 2.2 kg loss in carcass weight (Schaefer et al., 1992). Cattle off water for 36 h lost 7.6 kg in carcass weight (Schaefer et al., 1992).

4.4.2 Detrimental effects of curfew in combination with total **time off** feed and water (adding in transport & lairage) on meat quality.

There is little information of the effect of curfews on beef meat quality. The information that is available suggests that there is little effect of time off feed or water on the quality of meat from cattle.

Steers have been fasted for up to 28 days without affecting meat ultimate pH or dark-cutting levels (Lawrie, 1958). When rested steers are exercised to exhaustion, the ultimate pH was seldom raised although muscle glycogen was reduced (Howard, 1963). However in the same study, when exercise was given to cattle which had just experienced continuous rail travel, the ultimate pH was elevated. Thus it appears that physical stress does not greatly deplete glycogen reserves whereas psychological stress alone or in combination with physical stress can have a marked effect on quality (Warner, 1988).

4.4.2.1 Effects of transport (as an imposed time off feed and water) on Meat Quality

There is some early evidence that long periods of uninterrupted transport may increase the ultimate pH of beef muscles (van der Heever *et al.,* 1967; cited by (Shorthose, Harris & Bouton, 1972))but other studies have shown that it was difficult to deplete muscle glycogen of cattle by transportation (Howard and Lawrie, 1956; cited by (Shorthose et al., 1972)).

(Wythes et al., 1981) demonstrated that cows transported for 2055 km had higher loin pHu than cows transported for 460 km, even though the total time from farm to slaughter (8 days) and the time on feed and water was standardised. In Finland, the incidence of dark-cutting is increased with longer transport duration (Puolanne and Alto, 1980) whereas in Sweden, there is no relationship between transport duration and dark-cutting incidence ((Fabiansson, Erichsen, Laser Reutersward & Malmfors, 1984)).

4.4.2.2 Effects of saleyards (as an imposed time off feed and water) on Meat Quality

Cattle marketed via a simulated saleyard involving 100 km transport, unfamiliar yards overnight, handling and drafting and a further 100 km transport had reduced meat quality relative to cattle consigned direct to the abattoir (Warner et al., 1986). All cattle had continual access to water but the cattle marketed via the saleyard were off feed for 2 days relative to the direct consignment cattle being off feed for 1 day. The cattle marketed via the simulated saleyard had increased loin ultimate pH, lower muscle glycogen, darker muscle colour and a tendency for tougher meat then cattle consigned direct to the abattoir.

Ferguson et al (2006a) recently showed that loin steaks from saleyard cattle have marginally lower consumer meat quality scores and tend to have higher Warner-Bratzler shear force (ie. Tougher) compared to loin steaks from direct consignment cattle. The saleyard cattle in the study were off feed for 1 day longer then the direct marketing cattle. The cattle marketed via saleyards also had reduced muscle glycogen in two leg muscles (*semimembranosus* and *semitendinosus*) but this was not reflected in loin ultimate pH values (Ferguson et al., 2006a).

4.4.2.3 Effects of lairage (as an imposed time off feed and water) on Meat Quality

Cattle spending longer then 2 days in lairage in Victorian abattoirs have a higher incidence of dark-cutting, measured by ultimate pH (<1 day; 7.2% dark-cutting; 1-2 days, 7.4%; 2.5-3 days, 12%; > 3days, 15.1%; Warner et al., 1988). This is in spite of the fact that cattle in lairage for longer then 2 days were always given feed, usually in the form of hay. In Sweden, the ultimate pH of the loin increases with lairage periods greater then 9h ((Fabiansson et al., 1984). These results are in contrast to those for Queensland discussed below where a long transport necessitates a rest period at the abattoir prior to slaughter in order to reduce the incidence of dark-cutting.

The carcass yield, muscle glycogen, muscle pH and meat quality (including consumer eating quality) of cattle kept in lairage for 18 hr or 3 hrs on water, but no feed, was found to very similar (Ferguson et al., 2006b). Walker (cited by Warner and Pethick, 2000) showed that cattle kept in lairage with access to water but no feed for 1h, 1 day or 2 days had similar muscle glycogen in two leg muscles for all three lairage periods.

After transporting cattle for 30 h without rest, (Wythes et al., 1980a) reported that the loin pHu was lower if the cattle were rested on water alone (no feed) for 2 days rather then 1 day. Providing hay during this rest period did not affect the loin pHu values. In contrast, (Wythes & Underwood, 1980b) showed that after cattle had been transported for 36 h without rest followed by 22h on feed and water, the loin pHu was lower if the cattle were rested for 72h rather then 96h. In another study, (Wythes et al., 1980b) showed that bullocks off feed for 46 hrs or 70 hrs during farm yarding, 10 h transport and a period in lairage had no difference in loin pHu (or carcass weight).

In a study by (Shorthose et al., 1972), Shorthorn steers undergoing extended transport of 42 h by rail without rests produced similar pH values in both the loin, leg and *flexor profundus* muscles whether the steers were rested for 2 or 4 days with or without access to feed. Interestingly the initial pH of the *flexor profundus* was lower at 70 min post-slaughter in the cattle rested for 4 days relative to cattle rested for 2 days, suggesting an effect of rest duration on the rate of muscle glycolysis post-slaughter. The mean loin pHu was elevated above normal (5.64-5.72) for all of the groups undergoing the extended transport and either 2 or 4 days in lairage. Thus all carcasses would have been borderline for being dark-cutting using the present definition for dark-cutting in Australia of pHu>5.7.

4.5 Total time off feed and water - Aggravating Factors for Weight Loss and Meat Quality

Curfew on-farm and the conditions surrounding any time off feed and/or water has to be conducive to rest, otherwise the negative impact on carcass yield and meat quality will escalate.

4.5.1 Climate

Adverse climatic conditions can pre-dispose cattle to dark-cutting. The effects of weather on animals are exaggerated during transport pre-slaughter because they cannot employ their normal behavioural responses to avoid extremes. Wind reduces effective temperature considerably and rain will further increase the rate of heat loss from exposed animals. The effects of cold weather are greater the longer the cattle have been off feed. Low over-night temperatures in lairage increase the incidence of dark-cutting meat in lot-fed cattle (Shorthose, 1980). A high incidence of dark-cutting is reported when animal accustomed to mild conditions are subjected to severe climatic exposure (Howard, 1963). Furthermore, it is often changing seasonal conditions that pre-dispose cattle to dark-cutting such as continual cold weather followed by a hot spell (spring) or continual warm weather followed by a cold snap (autumn).

Cattle fasted indoors for 72 h had a lower loin ultimate pH and indications of lower muscle glycogen then cattle fasted outdoors for 60 h during cold environmental conditions in Victoria (Warner et al., 1986). These results suggest that cattle exposed to cold and wet environmental conditions and fasted prior to slaughter are at risk to exhibit a dark-cutting carcass.

4.5.2 Quality of transport conditions

The heart rate of cattle is reported to increase (indicating higher stress levels) over rough country roads and suburban roads involving multiple stop-starts relative to cattle transported under smooth freeway conditions (Eldridge et al., 1989).

Cattle transported at a low space allowance (0.89 m^2 /animal) have a lower carcass weight then cattle transported at a medium (1.16 m^2/animal) or high (1.39 m^2/animal) space allowance (Eldridge et al., 1989). There was higher bruise scores and number of bruises on the carcasses from the animals transported at the low and high space allowances relative to the medium space allowance (Eldridge et al., 1989).

4.5.3 Mixing

Cattle withdrawn from feed 24 h prior to transport and mixed with unfamiliar animals are more bruised then cattle mixed 2 h prior to transport (Dodt et al., 1979; cited by Eldridge et al, 1989). In addition, cattle mixed for 18 h prior to transport have higher heart rates (suggesting higher stress levels) prior to transport and during transport then cattle mixed 2 h prior to transport (Eldridge et al., 1989).

Objective assessment of meat quality indicated mixing steers one week before slaughter led to higher compression and a tendency for higher peak force values than control animals; however, these assessments were not matched by changes in sensory perception of meat quality (Colditz et al., 2006). The results confirm that mixing cattle in a feedlot less than two weeks before slaughter may compromise meat quality (Colditz et al., 2006).

4.5.4 Quality of lairage

Videos have been made of cattle in lairage pens at an abattoir overnight over 4 separate consignments (Eldridge et al., 1989). Each consignment was assigned to either a 'quiet' yard (little movement of other stock nearby) or a 'noisy' yard (close to unloading facilities with continuous stock movement for 5 hrs before midnight). The cattle in the 'quiet' yard had lower activity scores as well as significantly lower bruise scores.

It can be the conditions of lairage, not the duration, that impact on meat quality. Cattle allowed to rest 'peacefully' in abattoir lairage pens for 52 h had lower muscle pH then cattle subjected periodically to noise and disturbance (Wythes et al, 1988).

4.5.5 General

In order to minimise the effect of time off feed and water on carcass yield and meat quality, it is recommended that the guidelines provided by MSA for reducing dark-cutting, selling cattle through a saleyard and for handling cattle should be followed (see Appendix 1 and 2).

4.6 The role of feed quality and supplements in reducing negative effects of time off feed and water

Better nutrition pre-transport makes animals more bullet-proof to aggravating conditions. Muscle glycogen concentration is responsive to an increase in the level of nutrition by increasing the ME of the diet with barley, or other grain supplements (Knee, cited by Warner and Pethick, 2000). In addition, repletion of muscle glycogen after depletion is much faster on a diet with a high ME content (Gardner, cited by Warner and Pethick, 2000).

Cattle coming off poor pasture (eg. Winter pasture typical of SE Australia) are at greater risk for reduced meat quality as a consequence of curfews imposed between farm and slaughter. This is because they have lower muscle glycogen reserves (Warner et al. 1998) and thus the imposition of curfews or any other stress between farm and slaughter will increase the risk of a dark-cutting carcass. Warner et al. (1998) demonstrated that cattle grazed on a poor pasture 3 weeks pre-slaughter and marketed through a saleyard lost a lot more muscle glycogen then animals going direct to the abattoir, particularly compared to cattle grazing a high quality pasture pre-slaughter.

Various supplements and pellets have been developed to alleviate the loss in carcass yield and meat quality as a consequence of shipping animals for slaughter. Glucotrans® is a relatively simple preparation composed of salts (potassium and sodium chloride) and glucose which can be added to drinking water. Despite the simple nature of the preparation, inclusion in the water of cattle in lairage pre-slaughter has been found to promote a small increase in the glycogen content of muscle (Warner and Pethick, 2000). Cattle fed a Nutricharge® product in lairage generally showed a beneficial effect on muscle glycogen and dressing percentage after 42 h of lairage, but not after 16 h of lairage (Warner and Pethick, 2000) although there was no effect on meat ultimate pH. The inclusion of Nutricharge® in the feedlot mix on-farm reduced the loss of glycogen from muscle during the stress associated with 12 h pre-transport curfew followed by 6.5 h of transport to the abattoir (Warner and Pethick, 2000). In cattle fed Nutricharge® on pasture, it was difficult to get the cattle to eat the pellets but there were indications that the physiology of the muscle with regard to glycogen metabolism was affected (Warner, 1999). Although total muscle glycogen concentrations pre-slaughter had not been influenced, there was a tendency for treated cattle to show lower accretion rates of lactate post-slaughter in two muscles.

Other compounds such as magnesium oxide and magnesium aspartate have been fed to sheep and have shown beneficial effects in reducing depletion of muscle glycogen between farm and slaughter (Warner and Pethick, 2000) and thus may show some promise for feeding to cattle.

4.7 Summary

- Carcass yield losses will be reduced by minimising the time animals are off feed and/or water.
- Aggravating conditions surrounding the time off feed and/or water can increase the risk of poor meat quality and/or reduced carcass yield. Animals are more bullet-proof to aggravating conditions with better nutrition pre-transport.
- Curfew on-farm has to be conducive to rest.
- Guidelines provided by MSA for reducing dark-cutting, selling cattle through a saleyard and for handling cattle should be followed to minimise the impact of time off feed and water on carcass yield and meat quality.
- Cattle kept off water between farm and slaughter and not given an opportunity to rehydrate will produce lower carcass yields. Cattle off water for as short as 12h prior to slaughter have lower carcass yields thus it is recommended that access to water is provided at all times. Given access to water, cattle will rehydrate fairly quickly although it is not clear how long they need access to water to allow sufficient rehydration to eliminate carcass yield differences. The issue that needs attention is the availability and size of water troughs at saleyards and abattoirs and the quality of the water.
- Cattle kept off feed will start to catabolise their fat and muscle tissue after 1-3 days and this will reduce carcass yield. Feeding is recommended for cattle in transit for longer then 2-3 days. The challenge with feeding cattle in spell paddocks or lairage pens at the abattoir or at saleyards is the quality of the feed and whether the cattle are settling down and eating properly, or actually still catabolising body tissue. For this reason the recommendation is that the total time from farm to slaughter is always kept as short as possible. It is recommended that the possibility of a high quality tailored diet is investigated for cattle at risk. This could be an on-farm pre-transport supplement or for feeding at abattoirs. Provision of a specialised feed is not intended to allow the time from mustering and slaughter to be extended but to improve the carcass yield and meat quality of cattle at risk.
- The time between mustering and slaughter has a greater effect on losses in carcase weight then either distance travelled or transportation alone. When this interval exceeds 3 days, there are serious losses in carcase weight. For cattle which necessarily travel long distances at certain times of the year, the ideal rest/feed period and conditions is not clear and requires clarification.
- Bruising on beef carcasses reduces carcass yield. There is no direct evidence for time off feed and water influencing carcass bruising but there are a multitude of risk factors between farm and slaughter for carcass bruising. The known risk factors include long transport, high and low stocking densities in transport, mixing unfamiliar cattle, saleyard selling, noisy (not ‘restful’) lairage yards and chronic stress.

- During the period between farm and slaughter, there is limited evidence that time off feed and water have an influence on meat quality *per se*. For example long transport, saleyard selling and lairage beyond 2 days can all increase the incidence of dark-cutters and all involve elements of time off feed and/or water. But there is ample evidence that the conditions under which the time off feed or water are applied can detrimentally affect meat quality, in particular the incidence of dark-cutting beef carcasses. The risk factors include those given for bruising as well as exposure to cold and changing seasonal conditions. Thus attention must be concentrated on ensuring that the conditions of mustering, penning on the farm, loading, transport (including stocking density, duration, road type), unloading, saleyard management (where applicable) and abattoir lairage (stocking density, provision of quality feed and water, duration, flooring, 'restfulness'), are optimised. An example of this is that the 'lairage' pens at abattoirs are supposedly where the cattle rest and recuperate. But if the pens are not conducive to rest, the longer the period spent in lairage (off feed, with variable access to water) the greater the detrimental impact on both the carcass yield and the meat quality.

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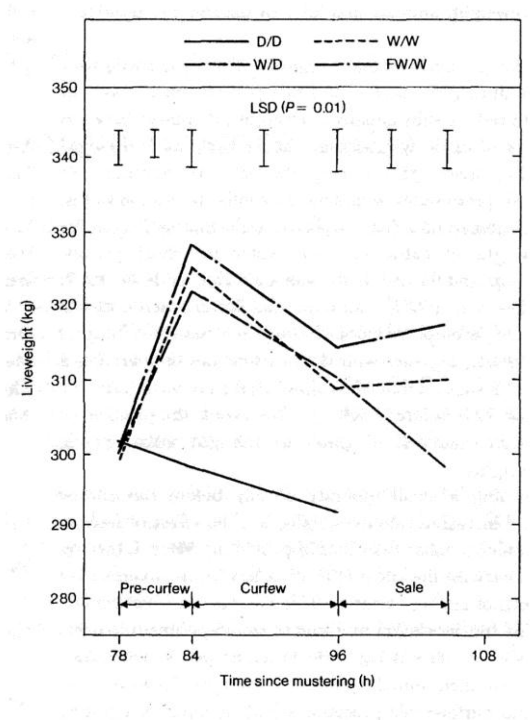

Figure 2: Effect of various curfew-sale procedures on liveweight of steers transported 1380 km to the saleyard. D/D – no water provided, W/D – water provided during pre-curfew only, W/W – water provided at all times, FW/W - feed and water provided during pre-curfew and water only at other times. (from (Wythes & Shorthose, 1981)).

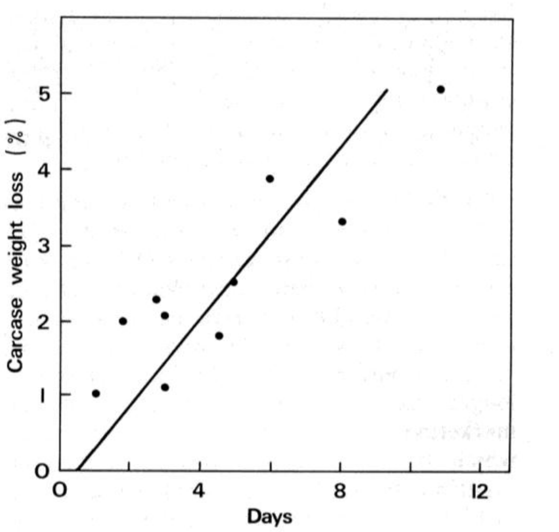

Figure 2: Recorded losses in carcase weight for Australian cattle deprived of feed and water intermittently for up to 12 days (from (Wythes et al., 1984)).

4.9 Appendices

4.9.1 Appendix 1: MSA requirements for handling cattle and for reducing dark-cutting

Key points to remember for reducing dark-cutting for MSA

High ultimate pH can have a detrimental effect on meat colour, texture, keeping ability and eating quality.
The following steps can help reduce stress in livestock prior to slaughter:
• Ensure livestock have good nutrition prior to slaughter.
• Muster and assemble stock as quietly and efficiently as possible.
• Handle livestock with care and avoid excessive force and noise.
• Familiarise animals to handling and train stock persons in handling skills.
• Maintain animals in their social groups.
• Ensure livestock have access to water at all times prior to consignment.

Key points for Handling Cattle for MSA

Cattle dispatched for slaughter must meet with the following requirements:
• Be continually grazed or fed rations to a level that is adequate for growth for a minimum period of one month prior to dispatch;
• Be handled and mustered quietly to reduce stress;
• Have free access to water until dispatch;
• Have free access to feed until dispatch, other than a minimum period required for preparation through cattle yards;
• Do not consign any cattle of poor temperament or with signs of severe stress;
• Do not consign sick cattle or cattle within a withholding period for any treatment;
• Do not mix cattle from different mobs or pens on the property within two weeks of dispatch;
• Do not dispatch cattle purchased or moved from another property/saleyard within one month of arrival;
• Load cattle quietly, preferably with no use of goads and electric prodders;
• Load cattle at the recommended densities set out in the trucking industry code of practice.

4.9.2 Appendix 2: MSA Requirements for Selling cattle through a MSA saleyard

On-farm responsibilities – all cattle production systems

- Producers must be registered with MSA to supply cattle for grading; (minimum two days for registration administration);
- No secondary sexual characteristics;
- No females which have calved;
- No females in calf;
- No cattle that have been severely sick or injured;
- No cattle of poor temperament;
- All cattle must reside on the property of dispatch for a minimum of 30 days prior to dispatch;
- Cattle are to be managed as a single mob for a minimum of 14 days prior to dispatch for slaughter;
- MSA Vendor Declaration must be delivered with the cattle *(as supplementation to other state-based requirements).*

Processor responsibilities

- Cattle shall be slaughtered within 36 hours after dispatch from the farm or property;
- 5 CMQ4 score point deduction for saleyard pathways.

Saleyard responsibilities

- Livestock exchange and saleyard to be licensed and have completed training as defined by the authorised authority;
- The livestock exchange or saleyard must have systems in place that will be monitored from time to time to verify compliance against the *MSA standards manual for saleyard consignment* as determined by the authorised authority;
- MSA vendor declaration to accompany cattle to and from livestock exchange and saleyard;
- MSA eligible cattle to be clearly identified at all times;
- Cattle groups are not to be mixed at any point from farm to slaughter, excluding split mobs;
- No cattle that have been severely sick or injured at the time of sale;
- Cattle shall be held on soft standing, within the livestock exchange or saleyard facility other than the minimum period of time required for the actual sale;
- Cattle within the livestock exchange or saleyard will have access to water at all times

5 Sheep meat quality

5.1 Author: Robin Jacob, Department of Agriculture WA

Executive summary

1. The length of time for feed and water deprivation period are important primarily for muscle weight and condition score. Meat quality traits are not likely to be affected by the length of the feed and water deprivation periods. In fact evidence suggests that tenderness may be improved due to activation of calpains by feed deprivation and due to water deprivation because of unknown reasons.

2. The maximum time periods for feed and water deprivation, allowable within the National Model Codes of Practice for the Welfare of Animals, are of sufficient length to decrease carcass weight and condition score.

3. Reducing the length of the pre-slaughter period may reduce weight losses due to feed and water deprivation. However because the relationship between weight loss and time tends to be curvilinear, the length of the curfew period on farm is a critical part of the pre-slaughter period, to minimise the effect of feed and water deprivation on carcase weight and condition score.

4. Stress and exercise during the curfew period are important determinants of muscle glycogen concentration and possibly hydration status at the time of slaughter. Prevention of stress and exercise during the pre-slaughter period therefore has a major role to play for the eating quality and retail appearance of red meat.

5. The degree of stress and exercise and their effects on meat eating quality are likely to be related to the nature rather than the length of the curfew period. Mustering, handling, transport technique, electric prodders, presence of humans and use of dogs are factors that may affect the nature of the stress response in relation to meat quality.

6. Finishing diets fed should contain sufficient metabolisable energy to maximise muscle glycogen concentration prior to consignment for slaughter. However more research is required to determine the effect of diet type on the rate of muscle glycogen turnover and the susceptibility to glycogen loss due to stress during transport.

7. Water loading strategies prior to the pre-slaughter period do not improve hydration status at the time of slaughter and may increase urine production during transport. Finding methods to increase water intake in lairage is an important area for future research.

5.2 Introduction

For the purpose of this review, the pre-slaughter period is taken to include curfew on farm, transport, saleyard, and lairage periods. There will be 2 transport periods prior to slaughter when animals are consigned to slaughter via saleyards, although this may not necessarily increase total curfew time compared to direct consignment to an abattoir. Season, age class, and regional differences may influence the timing of the different pre-slaughter periods. For example on farm curfew periods may be extended when pasture conditions cause poor faecal consistency. In practice the time of day that curfew commences may also be important by determining the digesta load at the commencement of curfew. Digesta load increases during the day in a grazing animal (Weston *et al.*, 1983). Starting curfew early in the morning could effectively increase curfew time compared to starting curfew late in the day.

Livestock are transported most commonly by road transport in Australia. Rail transport is used in parts of eastern Australia but is no longer used in Western Australia. Transport will include a sea voyage for animals that are produced in either of Tasmania or Kangaroo Island and then slaughtered on the mainland.

For meat quality the literature found in relation to the pre-slaughter period focussed mainly on glycogen concentration, with some information on sensory and visual properties of meat. Very little was found on the effects of the pre-slaughter period on the rate of pH decline post-mortem and no literature was found in relation to the effect of the pre-slaughter period on the colour stability of meat during retail display.

5.3 Time off feed

5.3.1 Weight loss

5.3.1.1 The rate of weight loss

Feed deprivation has been shown in a number of studies to cause reductions in live, carcass, liver and skin weights of sheep (Thompson *et al.*, 1987; Warriss *et al.*, 1987). Animal factors including liveweight, condition score, weaning history and feed type may influence the rate of live and carcass weight loss due to feed deprivation (Thompson *et al.*, 1987; Greenwood *et al.*, 2006). The relationships described in these studies are most often curvilinear but sometimes have been linear.

Thompson *et al* (1987) found the carcass weight loss was 3.5, 5.9, 7.3 and 7.7% of initial hot carcass weight at 24, 48, 72, and 96h, respectively for a 35 kg lamb of fat score 2.4 that had access to water. Liver weight decreases at a faster rate than for carcass weight in response to fasting. Warriss *et al* (1987) found a curvilinear reduction in liver weight of with a total loss of 28% after 72 h of fasting.

Thompson *et al* (1987) and Knowles *et al* (1995) found no effect of transport on the rate of weight loss additional to that due to feed and water deprivation. Furthermore (Knowles *et al.*, 1994) found that length of the transport period was not a major factor for lambs in determining the percentage of carcases with bruising hence the loss in carcase weight due to trimming of bruises. They found that shorn lambs were less likely to be bruised than unshorn lambs and attributed this to “wool pull” rather than trauma during transport.

5.3.1.2 Prevention and recovery of weight loss due to fasting

Information on the time required for carcass weight to recover following curfew suggests that 96 h or longer (Knowles *et al.*, 1993) may be required. The curvilinear nature of weight loss means each part of the curfew period should be as short as possible to minimise the effect on carcass weight. Reducing lairage time could have limited effect on carcass weight when a farm curfew period of 24 hours has been used. Interestingly Jacob (2004) found inconsistent effects of increasing lairage time on hot carcass weight. In this commercial study increasing lairage time from 4 to 48h caused a significant ($P<0.05$) reduction in carcass weight in only 3 of the 8 of lamb consignments measured.

5.4 Glycogen concentration

5.4.1 Glycogen depletion

Low muscle glycogen concentration at the time of slaughter is generally accepted to be the cause of "dark cutting meat" (Monin, 1981; Warriss *et al.*, 1989; Immonen *et al.*, 2000). Theoretically fasting should have little effect on muscle glycogen concentration because muscle glycogen phosphorylase is not activated when the insulin to glucagon ratio is low in association with fasting (Murray *et al.*, 1996). Furthermore high free fatty acid concentrations caused by fasting (Warriss *et al.*, 1989; Kent, 1997) inhibit phosphofructokinase 1 and can reduce glucose utilisation by muscle tissues (Johnson *et al.*, 1992). By contrast liver glycogen phosphorylase is activated by fasting and liver glycogen concentration depletes within 24hs of fasting (Warriss *et al.*, 1987; Jacob, 2004).

Exercise (Gardner *et al.*, 2001) and acute stress cause rapid depletion of muscle glycogen through activation of glycogen phosphorylase by adrenaline (Monin, 1981) and ATP utilisation. Exercise however needs to be anaerobic in nature to cause a depletion of muscle glycogen (Pethick *et al.*, 1991). The functionality of muscle is also important such that *m. longissimus thoracis et lumborum* LTL shows a smaller depletion of glycogen in response to exercise and adrenaline than do leg muscles (Crouse & Smith, 1986; Jacob, 2004).

Results from field studies have generally shown variable muscle glycogen responses during the pre-slaughter period. Jacob *et al* (2005) found that muscle glycogen loss occurred mainly during curfew and transport and not the lairage period. The reduction in glycogen concentration was greater in *m. semitendinosus* (ST) than *m. semimembranosus* (SM). Furthermore total feed deprivation period was not correlated with muscle glycogen depletion during the pre-slaughter period. This result is consistent with glycogen loss during curfew being due to stress or exercise rather than the fasting.

During the pre-slaughter period there may be several sources of stress but the contribution of feed and water deprivation to the hormonal stress response to lairage is likely to be limited. Parrott *et al* (1996) found that neither food or water or water deprivation for 48 hours induced release of either cortisol or prolactin. Other studies have shown that a hormonal stress response is seen during loading (Parrott *et al.*, 1998) and primarily at the commencement of transport (Trunkfield & Broom, 1990; Broom *et al.*, 1996; Hall *et al.*, 1998; Parrott *et al.*, 1998). Hall *et al* (1998) found that movement increased heart rate and cortisol release when stocking rate was low but vehicular noise caused an inconsistent response in sheep being transported by road. In summary these studies indicate that the nature rather than the length of time of curfew is the important criteria for eliciting a stress response.

5.4.2 Glycogen repletion

Feeding at least a maintenance energy ration is required to replete muscle glycogen. However the value of rest is complicated by behavioural factors and willingness to eat, when food is made available during the rest period (Shorthose, 1977). Shorthose (1977) found that 120 h was much more effective than 18hs of feed and rest for rams transported 1110 km. This is consistent with full repletion of muscle glycogen concentration requiring ingestion of a high energy diet for 48 hours or more (Gardner *et al.*, 2001). Water derived carbohydrate supplements, including glycerol and propylene glycol, are efficient sources of substrate for gluconeogenesis and can result in partial muscle glycogen repletion when used for less than 48 h during the lairage period (Gardner & Pethick, 2005). Propylene glycol also increases water intake and may be useful for the purpose of re-hydration during lairage.

In ruminants glycogen concentration is replenished in liver tissue before muscle tissue (Jacob 2003). With high ME intakes the glycogen concentration of liver tissue may return to maximum levels within 24 hours of feeding (Shorthose, 1977; Jacob, 2004). Short term feeding programs or supplementation with water soluble carbohydrate supplements may therefore improve liver quality and possibly weight more quickly than for muscle tissue. The value of this strategy as a part of the lairage procedure would depend on the financial value of liver.

There is some evidence that a short rest period of a few hours will reduce pHu unrelated to glycogen repletion (Jacob, 2004). Vetheraniam and Daly (2000) hypothesised that activity prior to slaughter may cause lactate inhibition of lactate dehydrogenase post slaughter. Lairage is likely to be more restful when humans are not present and sheep may require at least 1 m^2 in order to lay down during lairage (Kim *et al.*, 1994).

5.5 Other meat quality attributes

Feed deprivation has the potential to affect sensory eating quality due to effects on flavour and tenderness. A high pHu is associated with foreign flavours in sheep meat (Young *et al.*, 1993), so stress during curfew may have a detrimental effect on meat flavour if pHu is high due to stress. Increased concentrations of short and medium chain fatty acids and skatole have also been associated with “mutton” flavour in sheep meat, and these occur in highest concentrations when lambs are fed pasture (Young *et al.*, 2002). However, there appears to be no clear evidence to suggest that the length of the pre-slaughter period influences the concentrations of these compounds in red meat. Jacob *et al* (2005) found evidence of an interaction between age class and lairage time for liking of flavour. The flavour of LL from ewes was rated lower than for lambs when lairage period was 1 day but not for slaughter on arrival or 2 day lairage.

Ilian (2001) found an effect of fasting on calpain activity and tenderness. Again the magnitude of this effect in practice is difficult to ascertain and expression of any such effects may depend on processing practice. Jacob *et al* (2005) found an interaction between age class and lairage time for tenderness that was not related to sarcomere length, intramuscular fat concentration or pHu. The LL from sucker lambs was more tender than LL from ewes when the lairage period was 1 day but not when slaughtered on arrival or after 2 days in lairage.

Stress may interact with electrical stimulation for eating quality. Warner et al (2000) found that exercise just prior to slaughter, consisting of running for 1 minute followed by rest for 1 minute for a total of 10 minutes, caused a reduction in water holding capacity of lamb LL meat. This was associated with a change in ion concentration in blood, an increase in muscle temperature immediately post mortem, and a more rapid post mortem rate of pH decline. Subsequent studies showed that exercise prior to slaughter may cause meat to be darker in colour (Warner *et al.*, 2005).

5.6 Time off water

5.6.1 Hydration status

5.6.1.1 Factors causing dehydration

A pre-slaughter period in the range of 24-48 hours is of sufficient duration to cause dehydration in lambs. Jacob *et al* (2006) found measurable changes to the specific gravity of urine from lambs after 24 hours and changes in muscle tissue after 48 hours of water deprivation. Urine output may not reduce until 72 hours of water deprivation (Parker *et al.*, 2003). Bladder volume may be dependent on diet prior to slaughter and particularly the sodium concentration of the diet (Pearce *et al.*, 2004).

Stress can contribute to dehydration because elevated physiological concentrations of cortisol may induce a diuresis in ruminants unrelated to electrolyte loss (Parker *et al.*, 2003).

5.6.1.2 Recovery from dehydration

Knowles *et al* (1994) found that lambs did not drink until the second evening of lairage presumably because of unfamiliarity with the water source. Subsequently plasma osmolality initially increased and then decreased after12 hours of lairage. However other factors such as ambient temperature may also be important. Evidence suggest that lambs often do not drink in lairage at Australian abattoirs (Jacob *et al.*, 2005). Use of water loading strategies and electrolyte additives has not been successful for improving the hydration status of lambs under Australian conditions. Enticing lambs to drink is likely to be more important than putting electrolytes in the water to improve hydration status during lairage (Davidson & Jacob, 2005). Feeding salt during the lairage period may be contraindicated. Joubert *et al* (1985) attributed a condition known as "wet carcass syndrome" to a high salt intake in lairage when lambs had been dehydrated prior to lairage.

5.6.2 Carcass weight and fatness loss due to dehydration

5.6.2.1 Rate of weight loss

Water deprivation can reduce liveweight, carcass weight and retail meat yield (Shorthose & Wythes, 1988; Greenwood *et al.*, 2006; Jacob *et al.*, 2006). Losses in carcass weight due to dehydration can be difficult to measure. A carcass consists of fat and bone as well as muscle tissue. However reductions in GR tissue measurements have been consistently affected by water deprivation in a range of studies. Where reductions in carcass weight have been measured they have been in the order of 2% of hot carcass weight due to water deprivation (Jacob *et al.*, 2003). Water deprivation causes a reduction in muscle water content and muscle fibre size but little change in the weight or dry matter percentage of liver and skin tissue (Jacob *et al.*, 2006).

5.6.2.2 The relative importance of feed and water deprivation for weight loss

In some studies feed deprivation has been confounded with water deprivation so the relative contributions from water and feed deprivation to weight loss are difficult to estimate. Moreover deprivation of one factor will reduce the intake of the other. Some studies suggest that water is the key issue for weight loss for both feed and water deprivation. This may be due to sodium intake being an important determinant of total body water and extracellular fluid volume (Hix *et al.*, 1953). In a study where Hampshire X Suffolk wethers were subjected to feed and water deprivation for 3 days, 80% of the total body weight loss was body water (Cole, 1995) . Furthermore 57% of the total body water loss was from the intracellular component and 29% was from the gastrointestinal tract contents. (Hadi, 1986) found a greater loss in intracellular fluid than extracellular fluid in response to water deprivation in sheep and goats with this loss being greater in goats than sheep.

5.6.3 The effect of dehydration on meat quality traits

Water deprivation appears to have no effect on pHu (Lowe *et al.*, 2002; Jacob *et al.*, 2003), consistent with water deprivation failing to invoke an acute stress response. Warner *et al* (2002) observed an increase in tenderness of the LL from lambs after 2 days water deprivation. However there were no signs of dehydration in these lambs and the mechanism for this effect was unclear. Evidence suggests that water deprivation causes meat to be darker in colour although the mechanism for this is not clear either. Jacob *et al* (2006) observed an increase in lightness (L values) with no change in the hue of meat from deprived of water for 48 hours. Greenwood et al (2006) found a linear relationship between time off water (between 0h and 72h) and muscle colour score for goats.

5.7 The role of pre-curfew environment

5.7.1 Carcass weight loss

Kirton et al (1981) found that nutritional treatment prior to slaughter could affect the rate of live weight loss during transport. However this effect was attributed to carcass weight differences rather than the nutritional treatments. Several strategies have been attempted to reduce the effects of dehydration on carcass weight loss by causing "water loading" prior to transport. Pearce *et al* (2004) found that feeding saltbush (*Atriplex spp.)* during the finishing period improved the hydration status of lambs at the time of slaughter due to an increase in sodium intake. However subsequent studies showed that the total curfew time was important for this effect to occur. Whilst increased salt intake on farm increased water intake, natuiresis caused hydration status to return to normal after about 24 hours of feed curfew. Increased urine output would also likely occur during the transport period when high salt intake occurs on farm.
Studies into the use of the osmoregulator betaine and or salt prior to curfew have not demonstrated any benefits of such compounds for either hydration status or prevention of carcass weight loss in sheep (Jacob & Pearce, 2004). Furthermore (Davidson & Jacob, 2005) found no advantage of including a commercial electrolyte formulation in water on farm prior to curfew.

5.8 Meat quality

Whilst diet can affect muscle glycogen concentration at slaughter this is often due to muscle glycogen concentration being low prior to consignment rather than increased loss during curfew (Jacob *et al.*, 2005). Bray *et al* (1989) showed that the effects of a low energy diet and exercise caused by washing sheep prior to slaughter were cumulative in terms of causing glycogen depletion and a high pHu. Finishing strategies are therefore recommended to include a high metabolisable energy (ME) diet, to achieve a high muscle glycogen concentration prior to curfew. Such diets should be fed for a minimum of 7 days and are particularly important for shorn sheep when cold stress is imminent (Jacob *et al.*, 2001). Washing sheep prior to slaughter is generally not practised in Australia.

However Pethick *et al* (2005) reported that grain fed lambs lost more muscle glycogen during the transport lairage period than did pasture fed lambs. This resulted in lower muscle glycogen concentration and a higher pHu in lambs fed a high energy grain diet compared to a pasture diet. Jacob *et al* (2005) found a similar trend in commercial consignments of lamb. This finding might suggest that diet type had some influence on the mobilisation of glycogen in response to stress, possibly by increasing the rate of turnover of muscle glycogen. Similarly (Daly *et al.*, 1999) found that diet type was important for muscle glycogen concentration in addition to ME intake although this was not in relation to curfew. The ideal dietary regime for finishing lambs should provide a glycogen reserve that is both high and resilient to stress. This area requires further research in terms of the optimal diet prior to curfew to optimise muscle glycogen concentration at slaughter.

Weight loss during the finishing period can reduce intramuscular fat concentration and the perception of meat juiciness by consumers (Pethick *et al.*, 2005). Potentially this could be exacerbated by an extended feed deprivation period prior to slaughter.

5.9 Bibliography

Term	Definition
Ultimate pH (pHu)	The pH of meat reached when post-mortem glycolysis has finished approximately 48h after death.
Dark cutting meat	Meat that has a pHu above 5.7 and associated quality attributes including dark colour, decreased tenderness in the pH range 5.7-6, decreased keeping time, reduced drip loss and increased cooking time.
Transport	The process of moving sheep from one location to another using road transport. This period includes travelling time and stationary time.
Lairage	Enclosures for the purpose of holding livestock temporarily at an abattoir prior to slaughter. Lairage yards are usually covered with a roof and have a raised semi permeable floor.
Saleyard	A cental enclosure to which livestock are transported for the purpose of display and sale by auction. Saleyards are often not covered and have a soil floor.
Skatole	A white crystalline organic compound, C_9H_9N ,3-methyl-1H-indole, having a strong faecal odour formed from tryptophan in the rumen.
Calpains	A family of calcium dependent thiol proteases that proteolyze a wide variety of cytoskeletal membrane associated and regulatory proteins
Carcass weight	The weight of a carcass immediately post dressing and prior to chilling.
Glycogen	A large polysaccharide consisting of glucose subunits stored in liver and muscle tissues.
Sarcomere	The portion of a myofibril between two Z lines constitutes a single contractile unit termed a sarcomere.
Wether	Castrated male sheep
Pre-slaughter period	The total period from the time a sheep leaves the place of rearing (paddock or feedlot) until slaughter. This period includes curfew on farm, transport, saleyard, transport and lairage in the various different configurations that occur under commercial circumstances.
Curfew	The time that livestock are confined to a small enclosure on farm prior to transport.

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6 Review of the effects of food and water deprivation on animal welfare in ruminants.

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Executive Summary

This review forms part of a broader review examining the impact of curfews on animal welfare, meat quality and safety and the environment. The term curfew refers to a period of food and water deprivation prior to transport and/or slaughter. Specifically, the aim of this component of the broader review was to focus on the consequences of food and water deprivation on animal welfare in cattle, sheep and goats.

This review examined the impact of food and water deprivation from two perspectives. Firstly what are the direct effects of food and water deprivation, and secondly, does a period of food and water deprivation influence the capacity of animals to cope with subsequent stressors such as transport. Emphasis was given to those studies where the period of food and water deprivation ranged between 24 - 72 h which is similar to that experienced by Australian livestock during transport and marketing. Moreover, it was felt that short term curfews (6 – 12 h) were unlikely to be of major concern on animal welfare grounds.

In the context of animal welfare, the interpretation was restricted to physiological responses given that there has been little or no attempt to examine the behavioural and/or emotional costs associated with food and water deprivation. It was recognised that the feelings of hunger and thirst will be implicit during food and water deprivation, however, the emotional costs of these cannot be reliably assessed at this stage. However, it is likely that direct or indirect quantification of animal feelings or the way an animal perceives its state will be required as part of a more integrated and accurate assessment of animal welfare in the future.

In summary, the primary effects of food and water deprivation for periods between 24 – 72 h were increasing liveweight loss, dehydration and tissue catabolism. These associated changes in weight loss and metabolism were generally curvilinear with time. Rumen function, specifically microbial populations and activities, may also be adversely affected following food and water deprivation. Dehydration is undoubtedly the most significant animal welfare concern. However, the cattle data would suggest that although haemoconcentration and increasing urine osmolality were evident, the levels attained after 48 h of water deprivation had not reached critical thresholds indicative of clinical dehydration. It is likely that this would also apply to sheep and goats but this is less clear due to the paucity of published data. New research examining the response to food and water deprivation in smaller ruminants is required. Notwithstanding this, it was concluded that the current maximum limits of water deprivation as specified within the Australian Model Codes of Practice for the Land Transportation of Livestock, are appropriate on animal welfare grounds

There was insufficient scientific evidence to conclude that pre-transport curfew improves the capacity of ruminants to cope with transport. Clearly, this association requires urgent research attention as the results are central to any informed judgment of the impact of curfews on animal welfare during transport.

Finally, it was recommended that there would be value in developing strategies to improve the capacity/willingness of animals to consume water when it was available during lairage and in saleyards.

6.2 Introduction

It is inevitable that there will be short to moderate periods of restricted access to food and water for animals destined for slaughter. The key points where this can occur during and after the transfer of livestock to the abattoir include: (i) mustering and assembly prior to transport, (ii) transport, (iii) saleyard selling and subsequent transport and (iv) pre-slaughter lairage. Whilst food and water deprivation will normally occur at some point, in some cases, the period of deprivation can be substantially extended, particularly prior to transport, due to demands and selling conditions by transport operators and abattoir management, respectively. Curfew is the generic term used in livestock industries for the practice of enforced food or food and water deprivation prior to transport, sale or slaughter. Curfews are typically 6 – 12 h in duration and they are applied to reduce the gastrointestinal volume prior to transport, thus reducing the total amount of excreta in trucks and the level of faecal soiling on animals.

It is important to recognize that food and water deprivation is just one of several stressors that apply to livestock during the critical pre-slaughter phase. Others include: exposure to unfamiliar environments; transport; increased human contact and handling; changes in the social structure (i.e. through separation and mixing); and exposure to sudden changes in climatic conditions (Ferguson et al 2001).

Consequently, when evaluating the impact of food and water restriction on animal welfare, it has to be considered from two viewpoints. Firstly, what is the direct effect of food and water deprivation on animal welfare, and secondly, does the period of food and water deprivation affect the capacity of animals to cope with subsequent pre-slaughter stressors especially transport?

The purpose of this review is to explore these questions in more detail to identify knowledge gaps and to develop informed recommendations regarding the relevance and application of curfews during the pre-slaughter management and transport of livestock.

6.3 Animal welfare assessment

Before continuing, it is necessary to consider how animal welfare has and should be assessed in this context. This is problematic as there are no universally agreed set of welfare assessment criteria or methodologies. Historically, there has been a reliance on the measurement of both behavioural and physiological responses (eg. neuroendocrinal, immunological, autonomic and productivity measures) to specific stress challenges such as transport (Broom 2000, Knowles and Warriss 2000). More recently, there has been growing support for the inclusion of the assessment of animal's feelings or perception of its state (Duncan and Petherick 1991). Unfortunately, the momentum for this has been constrained by our capacity to accurately assess and interpret emotional states in animals. Notwithstanding this, it is increasingly apparent that the integration of the methodologies that quantify the animal's emotional, behavioural and physiological responses is required to facilitate a more complete and accurate assessment of animal welfare. In the context of food and water deprivation, the feelings of hunger and thirst will be implicit and assessment of them and their associated consequences for animal welfare will be required in the future.

For the purposes of this review however, the focus has predominantly been on the physiological responses to food and water deprivation, as there is a paucity of published data on behavioural responses. Moreover, emphasis was given to studies examining short to moderate periods of deprivation (24 – 72 h) which are similar to those experienced by livestock during transport and marketing.

6.4 Direct effects of food and water deprivation in ruminants

6.4.1 Liveweight loss

The most obvious effect from food and water deprivation is a loss in liveweight. The trend is typically exponential whereby the rate of liveweight loss is fastest during the initial 12 h of food and water restriction and slower thereafter. Shorthose and Wythes (1988) summarized the results from 26 cattle studies to reveal average losses of 4, 6.5, 9 and 10.5 % in liveweight following 6, 12, 24 and 48 h of food and water restriction (with or without transport). A similar pattern has been reported for sheep and lambs (Kirton et al 1971; Thompson et al 1987, Knowles et al 1995) and goats (Kannan et al 2002). The origin of the weight loss varies over the period of food and water deprivation. Typically in cattle, during the initial 24 – 48 h of fasting, the majority of weight lost originates from excretion of gastrointestinal tract (GIT) contents and urine. In a study by Phillips et al (1991), the combined weight of urine and faeces excreted accounted for 61 – 64 % of the total liveweight lost after 48 h of food and water deprivation. In sheep, this proportion is much lower (Cole 1995). As the duration of food and water deprivation extends beyond 48 h, tissue catabolism and dehydration increase in their contribution to liveweight loss. In their review, Wythes and Shorthose (1984) stated that carcass weight loss, an indicator of tissue catabolism and dehydration, was typically not observed until after 24 h of food and water deprivation in cattle. This period, before discernable changes in carcass weight loss are evident, can be extended up to 3 – 4 days when cattle have access to water during fasting (Kirton et al 1972). For sheep and lambs, significant changes in carcass weight may be evident much earlier, within 12 h of food and water deprivation (Kirton et al 1971; Thompson et al 1987).

The quantity and composition of the gut contents prior to the commencement of food and water deprivation has a large bearing in the magnitude of liveweight lost (Wythes and Shorthose 1984). Climatic conditions can also be influential, as temperature can affect gut motility and urinary output. Phillips et al (1991) reported that as the ambient temperature increased, the proportion of liveweight lost as excreta decreased.

6.4.2 Rumen function

The results from the literature would suggest that the effects of periods of food and water deprivation on rumen function, specifically the microbial populations and activities, are equivocal (e.g. Galyean et al 1981, Cole et al 1985, Loerch and Fluharty 1999). Further exploration of these results and the possible reasons for the differences between studies is dealt with in more detail by Entwistle (2006).

6.4.3 Blood chemistry

There is a reasonable body of literature examining the effects of either food deprivation or food + water deprivation on blood hormones, metabolites and chemistry in ruminants. From these studies, there is a general trend of changes in key parameters, particularly those that are indicative of protein and fat catabolism and haemoconcentration/dehydration. These are summarized in Table 1.

Changes in the total and differential leucocyte counts (indicator of immune response) during food deprivation have also been examined in cattle (Cole et al 1988, Schaefer et al 1990 1992) and goats (Kannan et al 2002). The results generally indicated that there was minimal change in leucocyte numbers.
In general, food or food and water deprivation over varying periods up to 72 h did not affect blood cortisol concentration in cattle (Gaylean et al 1981, Vanderwalt et al 1993, Parker et al 2003), sheep (Warriss et al 1995, Horton et al 1996) and goats (Kannan et al 2000). Cortisol secretion is regulated by the HPA axis and it increases in response to a wide range of stressors but particularly those that are psychological in nature. The general lack of a cortisol response would suggest that food and water deprivation up to 72 h was not psychologically stressful to ruminants. However, it is reasonable to assume that animals will experience hunger and thirst. Moreover, it is possible that measurements of plasma cortisol concentration which reflect activation of the hypothalamic-pituitary-adrenal axis may not necessarily reflect these states.

Table 1: Typical response in selected blood parameters to food deprivation or food + water deprivation over varying periods up to 72 h in ruminants

Blood Parameter	Indicator	Response to Food Deprivation or Food + Water Deprivation
Glucose	Carbohydrate metabolism	**Decrease** (may show slight increase initially up to 24 h)
NEFA	Lipolysis	**Increase**
Urea Nitrogen	Protein catabolism	**Increase**
Total protein	Haemoconcentration/dehydration	**Increase**[*]
Albumin	"	**Increase**[*]
Haematocrit or PCV	" & HPA activation (fear)	**Increase**[*]
Haemoglobin	"	**Increase**[*]
Osmolality	"	**Increase**[*]
Cortisol	HPA activation (fear)	**Minimal change**
PCO_2	Blood-acid base balance	**Decrease**

[*] Response during food + water deprivation. Food deprivation alone may only result in minimal changes to these parameters.
HPA hypothalamic-pituitary-adrenal axis WBC – White blood cell count
(From: Galean et al 1981, Cole et al 1988, Schaefer et al 1990 1992, Phillips et al 1991, Vanderwalt et al 1993, Parker et al 2003[a] – Cattle; Gaal et al 1993, Knowles et al 1995, Horton et al 1996 – Sheep; Kannan et al 2000 – Goats)

6.4.4 Urine volume and chemistry

Reduced fluid intake causes pronounced changes in urine output and chemistry. Specifically, urine output declines with a commensurate decrease in sodium and chloride ion concentrations and an increase in nitrogen, specific gravity and osmolality (Igbokwe 1997, Carlson 1997). However, there have been exceptions to this general trend. In a study by Schaefer et al (1992) involving 12, 24 and 36 h of food and water deprivation in cattle, urinary chloride increased 3.5 fold from 24 to 36 h. Urine osmolality declined from 12 to 36 h but the trend was not significant.

Summary
The associative effects of food and water deprivation for periods up to 72 h are liveweight loss, dehydration, lipolysis and protein catabolism. These associations are generally not linear. The psychological stress associated with feed and water restriction appears quite small based on blood cortisol concentration. However, this should not be interpreted that the animals do not experience hunger or thirst.

6.5 Effect of pre-transport food and water deprivation on the response to transport

The application of pre-transport curfews (ie periods of food and water deprivation on-farm prior to transport) has in part been justified on animal welfare grounds. The anecdotal reports from livestock transporters are that cattle and sheep tend to travel better following pre-transport curfews. One of the primary benefits observed was the reduction in number of animals (primarily cattle) that lie down or lose their balance on the truck during the journey. The risk of bruising and injury increases considerably when animals go down (Tarrant and Grandin 2000) and drivers are required to encourage these animals back to their feet which in turn, may cause additional stress in both the downed animal and others in the truck. Regular stopping to attend to downed animals will also prolong the transport duration. One factor thought to contribute to the curfew mediated reduction in downer animals was the reduced volume of excreta on the truck floor and therefore reduced risk of slippage and falling.

There is very little published data corroborating these anecdotal views. Gregory et al (2000) in New Zealand undertook a study examining the effect of different pre-slaughter feeding treatments on the amount and consistency of excreta voided during 2 hours of transportation to the abattoir. Pasture finished cattle were either: (i) fed hay for 48 (ii) fed hay for 24 h, (ii) fasted for 24 h or (iv) not fasted (remained on pasture) prior to transport (2 h) to the abattoir. The cattle had access to water during their pre-transport feeding treatments and in lairage. As expected, fasted cattle produced significantly less excreta that the non-fasted or hay fed groups. Their results also confirmed earlier observations (Bass and Duganzich 1980) that digesta tends to become more liquid over time of increasing food deprivation. However, the faeces from the non-fasted pasture cattle were significantly more liquid than the fasted group. Unfortunately, no behavioural observations were made during transport. However, these results confirm that non-curfewed cattle will not only produce more excreta during transport but it is also likely to be more liquid. Although not stated, it is presumed that the pasture conditions in the study by Gregory et al (2000) were typical of those in New Zealand (ie. high quality, relatively lush temperate pasture). If so, one question that arises is whether these results are equally applicable when cattle are derived off poorer quality or drier Australian pastures.

Whilst the volume of excreta and indeed the design and construction of the stockcrate floor contribute to losses of balance and slippage, it is pertinent to highlight that stocking density and driving events (eg. braking, cornering) are also major factors in this context (Eldridge 1988, Tarrant et al 1992, Cockram et al 2004).

No clear conclusions can be drawn with regard to the interaction between pre-transport food and water deprivation and the response to transport as there is a distinct lack of published data. The search only revealed three cattle studies that were relevant. In the study by Gregory et al (2000), described above, there were no differences in plasma cortisol or protein concentration at slaughter between the fasted and non-fasted groups. Urine sodium concentration was significantly higher in the fasted group suggesting that these cattle may have been more dehydrated. Irish researchers (Earley et al 2004) contrasted the treatments of 8 h of fasting (with access to water) versus no fasting on the responses to 8 h of road transport. Apart from a difference in liveweight lost after transport (9.4% fasted and 7.2% non-fasted), there were no or minimal differences in blood chemistry and haematology. Given this, they concluded that the combination of 8h of fasting and 8 h of transport did not negatively impact on animal welfare. The salient point here is that cattle had access to water during the curfew period. Jacobsen and Cook (1997) compared different periods of pre-transport holding time (3, 8 and 20 h) with and without access to feed (silage) prior to 2 h of transport in bulls. They found that holding time and conditions affected the stress response to transport. The plasma cortisol levels were considerably higher prior to (46.5 – 60.7 nmol/l) and subsequent to transport (92.1 – 108.8 nmol/l) in the 3 h group compared to the 8 and 20 h groups (28.9 – 34.3 nmol/l pre-transport and 21.5 – 30.8 nmol/l post-transport). They concluded that pre-transport holding periods of <8h for bulls may be insufficient to allow adequate recovery from the process of mustering, and yarding.

In this context, transport operators have asserted that cattle that are curfewed prior to transport show less desire to lie down during transport. There is some limited evidence that supports this assertion. Lying behaviour during rail transport was particularly evident in a Queensland experiment when cattle consumed excessive volumes of water prior to the journey (J.Lapworth *personal communication*). The excess consumption was due to the inclusion of sugars in the water.

Summary
There is a paucity of scientific data to support the anecdotal views from livestock transporters that pre-transport curfews facilitate improvements in the capacity of cattle and sheep to cope with transport. The application of pre-transport curfews will result in less excreta in trucks but it is not clear whether this reduces the amount of slippage and losses in balance during the journey.

6.6 Comparative physiological responses to food and water deprivation and transport

There are a small number of investigations comparing the physiological effects of similar periods of food and water deprivation or transport in both cattle and sheep. The results from these studies are summarized in Table 2.

In their review of research published prior to the 1980s, Shorthose and Wythes (1988) reported it was questionable whether the loss in liveweight or carcass weight due to transport was higher than that from food and water deprivation alone. In investigations since then, weight loss was higher following 48 h of discontinuous transport in cattle (Phillips et al 1991), but in sheep the results were equivocal (Knowles et al 1995, Horton et al 1996). The percentage of weight loss as excreta was higher in transported cattle compared to those deprived of food and water for 48 h.

On the basis of the limited number of studies presented in Table 2, it would also appear that the differences in the physiological responses to food and water deprivation compared to transport are negligible.

Collectively, these results seem counterintuitive given the additional psychological stress and physical demands that occur during transport. Psychological stress can induce diuresis (Parker et al 2003[b]) and increased gastrointestinal tract motility. Therefore, it is reasonable to expect that liveweight losses might be higher during transport. The psychological stress associated with transport, based on changes in heart rate and plasma cortisol concentrations, is generally highest during loading and initial phases of transport (Eldridge et al 1988, Warriss et al 1995, Pettiford et al unpublished). Beyond that, animals generally habituate to the transport conditions. Consequently, the elevated stress response is not sustained over the entire journey and this may account for the equivocal results with regard to liveweight loss. The effort to maintain balance during transport would also be expected to incur increased muscular demands compared to that during food and water deprivation only. However, Knowles et al (1995) reported no difference in plasma creatine kinase levels. Creatine kinase is an enzyme associated with energy metabolism in muscle which is released following a change in the permeability or damage to muscle cell membranes and has been used as an indicator of muscle use/damage in transport studies (Knowles and Wariss 2000). Whilst useful, measurements of muscle glycogen depletion may be more informative in this context. Some care also needs to be exercised with respect to the results of Phillips et al (1991) as the cattle were not transported continuously over the 48 h period.

Table 2: Summary of results from studies comparing the effects of food and water deprivation versus transport on physiological response in cattle and sheep.

Reference	Treatments	FFA (mmol/l)	Glucose (mmol/l)	Urea N (mmol/l)	Cortisol (nmol/l)	Osmol. (mOsmol/l)	Protein (g/dL)	PCV (%)	pCO_2 (mm HG)
Cattle									
Galyean et al (1981)	0 h FWD		4.12[ab]	9.17[a]	86.4	290	6.7[a]		
	32 h FWD[#]		3.72[a]	7.48[ab]	105.7	297	8.3[b]		
	32 h Transport		4.95[b]	5.96[a]	51.9	296	8.3[b]		
Phillips et al (1991)	48 h FWD		5.11[a]	No diff.			No diff.	No diff.	
	48 h Transport[*]		7.55[b]						
Schaefer et al (1992)	12 h FWD[**]		6.61			287		43.0	23.6
	24 h FWD[**]		6.42			295		41.6	22.5
	36 h FWD[**]		6.56			292		43.3	24.4
Parker et al (2003)	0 h FWD						6.4		42.6
	60 h FWD						8.1		36.1
	12 h FWD + 48 h Transport						7.9		37.8
Sheep									
Knowles et al (1995)	24 h FWD	1283[a]	3.41[a]	9.48[a]	82.5	291	6.8	37.6	
	24 h Transport	788[b]	4.49[b]	8.15[b]	85.3	293	6.8	36.8	

[#] FWD – food and water deprivation. No diff. – least square means not reported due to non significant differences between the treatments (P>0.05)
[*]Cattle were held in metabolism crates on the truck. Transport was not continuous (10 h transport + 14 h stationary + 8 h transport + 16 h stationary)
[**]Cattle were transported for 4 h prior to receiving their food and water deprivation treatments in lairage.

Summary
The differences in the physiological responses to similar periods of food and water deprivation or transport are negligible based on the available evidence.

6.7 The impact of pre-transport curfews on ruminant welfare

Under the Australian Model Code of Practice for the Land Transportation of Cattle, the maximum allowable transport duration is primarily determined by the maximum time that stock can be deprived of water. For mature dry cattle, the maximum duration is 36 h. However, this can be extended to 48 h if the animals are not displaying obvious signs of fatigue, thirst or distress and if the extension allows the journey to be completed within 48 h. For mature healthy sheep, the maximum proposed time is 32 h but this can be extended to 38 h. Implicitly, these maximum durations also include any period of pre-transport curfew where access to water is restricted. Importantly, this would not apply to pre-transport curfews that allow access to water but not food.

For the majority of cattle, sheep and goats that are directly consigned to slaughter, it is unlikely that the period of water deprivation will exceed the maximum limits under the code. One of the mitigating factors here is the availability of water during abattoir lairage. However, it needs to be remembered that even with access to water, not all animals will drink. Limited access to watering facilities, unfamiliarity and neophobia all contribute to the variability in drinking behaviour in novel environments. A recent study by Jacob et al. (2006) has shown a high incidence of dehydration in Australian slaughter lambs but the relative importance of water access, unfamiliarity and neophobia remain unknown.

However, for some marketing/transport pathways, it is likely that the maximum limit will be exceeded and therefore animal welfare may be compromised. It is also pertinent to highlight that under the current regulatory framework governing animal welfare in Australia, there are limitations with regard to the capturing or information than enables assessment of compliance with the code.

From an animal welfare perspective, curfews will elicit hunger and thirst and their expression will depend on curfew duration and the physiological condition of the animals prior to the commencement of the curfew. The psychological impacts of hunger and thirst in livestock cannot be reliably quantified at this juncture. Consequently, we are reliant on quantifying the biological costs via physiological measurements. Physiologically, restricted food and water intake leads to altered metabolism, increased tissue catabolism and dehydration. Of these, dehydration is undoubtedly the most significant welfare concern. Transport or fasting studies where cattle were deprived of food and water up to 48 h clearly show haemoconcentration indicating some level of dehydration (Schaefer et al 1990 1992, Phillips et al 1991, Vanderwalt 1993, Parker et al 2003[a], Pettiford et al unpublished). However the level of dehydration even after 48 h could not be classed as being of clinical concern. For example, in a recent Australian study (Pettiford et al unpublished) where cattle were transported for 48 h (no pre-transport curfew), many of the key plasma measures (eg. osmolality, total protein, PCV) were still within normal expected physiological ranges. This outcome can be partly attributed to the ruminal reservoir of fluid which acts as a useful buffer during periods of water restriction (Knowles and Warriss 2000, Parket et al 2003[b]). Unfortunately, the picture is far less clear with regard to sheep and goats. Recent results by Parker et al (2003[b]) indicate that sheep may also be reasonably tolerant of considerable periods of water deprivation as reductions in urinary output were only evident after 72 h of water deprivation.

There is insufficient scientific evidence to conclude that pre-transport curfew improves the capacity of ruminants to cope with transport. Clearly, this association requires urgent research attention as the results are central to any informed judgment of the impact of curfews on animal welfare during transport.

6.8 Conclusions and Recommendations

The immediate effect of a short-term curfew (6 – 12 h) prior to transport is unlikely to be of significant concern on animal welfare grounds. However, during marketing or movement of livestock, the cumulative period of food and water deprivation extends well beyond that associated with the pre-transport curfew period. When the total period of water deprivation in particular, extends beyond 48 h in mature cattle, animal welfare is likely to be compromised due to dehydration. It is not clear whether the situation is similar for sheep and goats based on the limited evidence and this represents a knowledge gap. Notwithstanding this, it is concluded that the current maximum limits for water deprivation specified within the Australian Model Codes of Practice for the Land Transportation of Livestock, are justifiable on animal welfare grounds.

There is a high priority for new research to quantify the effects of curfew on the behavioural (especially slippage and lying behaviour) and physiological responses to transport. Specifically, the aim of this research is to address the question of whether curfews facilitate improvements in the capacity of animals to cope with transport >12 h in duration.

Finally, there may be value in examining strategies to improve the capacity/willingness of animals to consume water when it was available during lairage and in saleyards. These may range from upgrading the existing watering facilities, improving water quality and palatability and prior exposure and training to novel drinking systems.

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7 Current recommendations regarding curfews

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Executive Summary

1. This report aims to summarise current recommendations under state and commonwealth regulations or codes of practice and to compare current risk factors with the regulations and codes.

2. The welfare of livestock during curfew in Australia falls under the jurisdiction of a range of regulations and codes of practice. Whilst administration and supporting legislation for livestock welfare are state based, the basis for most codes is the National Model Codes of Practice (NMCOP).

3. Disparities between recommendations and implementation of recommendations between states have led to plans to change NMCOP from the current format into an auditable standards based system of "Australian Standards and Guidelines for the Welfare of Animals". This change is expected to be implemented by 2010 under the auspices of Animal Health Australia.

4. This current state of flux presents an excellent opportunity for curfew recommendations based on welfare to be harmonised with broader objectives for food safety, meat yield and meat quality issues.

5. NMCOP contain recommendations in relation to rest, time off feed, time off water and stress minimisation. For the time off feed and water recommendations, ranges and maximum times are specified for component (on farm, transport, saleyard, lairage) and composite (total time) curfew periods.

6. Although time period recommendations are clearly documented, a clearer interpretation of time periods relevant within the context of a pathway to slaughter is necessary, to enable comparison between recommended and actual time periods.

7. The maximum allowable time off water for adult dry cattle (> 6 months of age) is 36 hours. For dry sheep the maximum permissible time off water is 36 hours while for lambs under 6 months 20 hours is recommended. There are provisions for longer times for extended transport.

8. The maximum allowable time off feed for the curfew + transport period for cattle is 48 hours and for sheep 32 hours. However the total time off feed for the entire farm to slaughter path is noted stated.

9. Curfew can be reinstated after a rest period. For example prior to reloading after a rest period within an extended transport period, or towards the end of a lairage period prior to slaughter.

10. Recommendations in relation to stress minimisation include reference to facility design, use of electric prodders and the muzzling of dogs used to move livestock.

The second objective of this report, to compare current risk factors with the regulations and codes, was done in a preliminary way only. There is little published information about compliance of industry practice with NMCOP. The nature of recommendations within NMCOP would make quantification of compliance difficult. Furthermore uniform adoption of standards across Australia is very unlikely given the differences between states, particularly in the method of implementation of NMCOP. Finally there is very little requirement within NMCOP for monitoring of basic animal physiological indicators of well being. Welfare outcomes may therefore not be assured even when NMCOP recommendations are satisfied.

7.2 Introduction

This review has considered the purpose of National Model Codes of Practice (NMCOP), the legislative framework supporting NMCOP, plans to change NMCOP to "Australian Standards and Guidelines for the Welfare of Animals", and a discussion of current recommendations within NMCOP.

The word curfew is written infrequently in NMCOP, perhaps to avoid confusion with different terminology. Curfew is defined by the Macquarie dictionary as the application of restrictions to people at a regular time, such as nightfall, and is not defined in an animal or animal movement context. Specifically the word curfew appears in the draft land transport of sheep June 2004 , land transport of cattle, and animals at saleyards NMCOP's (Table 1). Although not formally defined in NMCOP, "curfew" is generally applied to the period immediately prior to transport, either on farm or at saleyards, or following a rest period during a prolonged transport period.

The terms "emptying out" and "holding period" apply to this period of time as well, hence the potential for confusion between different terms for the same period. In section 9.2.6 NMCOP transport of cattle, "emptying out" is defined as the deliberate and variable period (0-12 hs) of water and or feed deprivation, aimed to minimise faecal and urine spoilage of the transport vehicle and subsequent problems with animals slipping. This NMCOP also refers to "dry curfew" not being recommended at saleyards without any differentiation in practical terms to "wet curfew". Wythes (1982) defined dry curfew as the denial of food and water and wet curfew as denial of food only with access to water for a statuatory period.

7.3 Purpose of NMCOP

An important function of NMCOP is to form the basis for legal argument about livestock management practices. However a code breach is likely to be prosecuted only when accompanied by an adverse welfare outcome. Monitoring compliance with NMCOP is not routine and to date prosecutions for breaches of NMCOP recommendations have been an uncommon event.

NMCOP also have the function of being a point of reference for industry bodies as well as government agencies. Some industry bodies provide their members with literature that include animal welfare information. For example "Is it fit to load? A guide to the selection of animals fit to transport in WA" is supported by a range of bodies including the Livestock Transporters Association, Pastoralists and Graziers Association and Western Australian Farmers Federation. Several quality assurance programs such as Truckcare, Flockcare, and Cattlecare also have an animal welfare component. All of these activities refer to or draw on the NMCOP as the basis for animal welfare recommendations.

7.4 Legislative frameworks supporting NMCOP

Livestock welfare legislation in Australia is largely state based (Table 2). This situation arises from the Constitution providing States and Territories with sovereign powers in matters affecting their rural industries. Whilst commonwealth legislation does apply to export livestock, this legislation can be used to remove an export licence only and not to prosecute welfare breaches. NMCOP are written by the Primary Industry Ministerial Council (PIMC) with advice from the Primary Industry Standing Committee (PISC). Each state has representation on PISC, hence an input into the content of NMCOP. The aim of this system is to promote uniformity between the state codes whilst keeping the authority for prosecution of regulations within state legislation (Table 3 and Figure 1).

Codes of practice are adopted by state legislation in all states, although not in the ACT. State authorities use the NMCOP without major change, except in the case of 2 states. Victorian and Tasmanian authorities have rewritten the model codes of practice to fit their own purposes, although the intent of their codes appears similar to the NMCOP. Whilst the existence of several different sets of codes of practice is an issue, the more important anomaly is the difference between the states in the way they implement the codes of practice for the welfare of animals.
Firstly the state government agency that administers codes of practice varies between states. Primary industry departments are the lead agency for animal welfare legislation in QLD, NSW, Victoria and Tasmania. In South Australia, Northern Territory and Western Australia various other departments are the lead agency. In addition to departmental inspectors, police and RSPCA officers have animal welfare powers in New South Wales, Queensland, South Australia and Western Australia.
Secondly, there are regulations to enable prosecution, in the case of non compliance with specific recommendations within codes of practice, accompany legislation in the states of Victoria and South Australia only. In other states, codes of practice have less power, such that compliance or otherwise can be used only in support of evidence to either defend or prosecute an animal welfare breach.
In summary, systems for both the administration and enforcement of codes vary between states. In a practical sense, different standards may be implemented even when different states use the same recommendations from NMCOP. A particular scenario affected by this disparity is the interstate movements of livestock because no single jurisdiction regulates interstate movements of livestock. Regulation of welfare breaches during the course of interstate movements is therefore problematic under the current legislative framework. Currently a draft “Animal Welfare Cross Jurisdictional Incident Response Plan” is being considered by Animal Welfare Working Group to confront this problem.

7.5 Proposed change from NMCOP to Australian Standards and Guidelines for the Welfare of Animals.

NMCOP have been in place for about 20 years and have been updated on an ongoing basis. Subsequent to a review of this process in 2005 (Neumann, 2005), Animal Health Australia have foreshadowed a major revamp of the NMCOP system (Bond, 2006). In a practical sense, the significant change will be the replacement of NMCOP with Australian Standards and Guidelines for the Welfare of Animals (ASGWA). ASGWA will consist of:

- Australian Welfare Standards. A succinct set of minimum welfare standards that will be referenced in relevant legislation of each State and Territory. [As far as practicable, the Standards should be consistently enforced across all jurisdictions. They should be outcome-focused and capable of verification for audit purposes.]
- Industry guidelines that may mirror the current industry best practice and meet QA requirements.

Currently NMCOP focus on animal husbandry and management practices with some reference to "standards". The intention is to have new standards that are uniformly enforceable across Australia in place by 2010.

The report to NCCAW36 in September 2005 from the "Future Regulation and Management of Welfare Workshop" outlines the scope of the changes proposed. Stated in the summary is a commitment to science based inputs as a critical element in the development of standards. Also that animal welfare standards and codes are to be included in legislation that addresses animal management and security of production animals rather than 'cruelty' based legislation. This proposal presents a historical opportunity for animal scientists to have a major input into the content and implementation of new ASGWA.

7.6 Recommendations in NMCOP

The key management factors currently in codes of practice relate to rest, time off feed, time off water and stress minimisation.

7.6.1 Rest

Rest is recommended after periods of physical exertion, including mustering and extended transport. Access to feed and water is often indicated in rest periods, except in the case of the period after arrival at slaughter establishments. A curfew period can follow a rest period to comply with transport or sale requirements.

7.6.2 Time off feed and water

Specifications for recommended times off water and or feed are featured in all codes, both for component and composite time periods including "curfew", transport, saleyard and slaughter establishments. NMCOP are not clear about supply of feed and water during rest as they sometimes state food and water and other times they don't. Rest appears to include food and water except in the case of lairage, in which case rest means access to water but not feed.
Although times are clearly stated, discretion allows for large differences between different pathways (Tables 14, 15 and 16).
Interpretation of recommendations also depends on the level of expertise of the stockperson. In NMCOP saleyards section 2.5.1.3 it is stated; "where clinical or post-mortem evidence indicates dehydration of animals has occurred, then watering arrangements for stock must be modified to remove the problem" without there being any accompanying description of dehydration.
Time off water is stated to be more critical to the animal than time off feed (section 9.2.5 of the NMCOP for the transportation of cattle), although this appears to be confounded because water withholding recommendations can be more restrictive than those for feed (Appendices, Table 7).
There is some degree of contradiction amongst different NMCOP and other industry documents. In the National Vendor declaration and Waybill for sheep and lambs,

owners are asked to state the hours off feed and water before transporting. This might be taken to imply that curfew should include feed and water deprivation. However NMCOP states that cattle should have access to water but not feed during curfew whilst sheep should have access to feed but not water during curfew.
Water trough dimensions are specified in NMCOP saleyards section 3.7 (Table 4). In addition it is stated that small troughs are preferable to large troughs but that nipple or bowl drinkers should not be used as the sole source of water for sheep and cattle. However this specification is not uniform or as well defined across all NMCOP. In the NMCOP slaughter establishments section 2.5.1.3, the requirements for water trough size are stated as: “troughs should be of sufficient size to allow all animals to drink within an hour of arrival”.
In the NMCOP saleyards, it is recommended that “animals travelling long distances be given sufficient time after arrival at the saleyards to feed, water and rest in accordance with any pre-sale curfew restrictions” without clarification of what constitutes a long distance or sufficient time. The quantities and qualities of water or feed to be supplied are generally not detailed in NMCOP. Palatable dry roughage is an example of the way in which a suitable feed source is described for sheep prior to transport. Victorian codes of practice are slightly more specific than NMCOP in relation to water quality.

7.6.3 Stress minimisation

The word stress is mentioned many times in the NMCOP in a descriptive way. Specific ways cited to minimise stress are given in relation to: electric prodders, dogs, transport and loading times, and environmental extremes. Electric prodders are deemed not suitable for use with sheep. Use of dogs is condoned for loading and is described in Appendix III of the slaughter establishment code and in the land transport codes. Dogs are not to be used with young calves and should be muzzled particularly if prone to biting. Assessment of environmental extremes are completely discretionary and no reference is made to specific meterological data. There are specific recommendations for stocking density, dimensions of races and loading ramps which could all impact on stress.

7.7 Other relevant standards

Animal welfare standards for livestock processors is a document produced from a collaborative project between the Australian Meat Industry Council and the Animal Welfare Centre. This is used by Australian Quarantine Inspection Service (AQIS). Importing countries also have standards in relation to time off food and water. For large abattoirs that sell meat in to a range of different markets, one standard such as the European Union may be used as the general requirement for all livestock slaughtered at the establishment.

7.8 Comparison of current industry practice with the regulations and codes

7.8.1 Introduction

To facilitate a comparison of current industry practice with NMCOP summary lists of time recommendations in current and draft NMCOP (Tables 4-13) have been made along with some examples of pre-slaughter pathways (Tables 14-16). These pathways were chosen as relatively extreme examples with substantial transport components. Additionally the curfew periods involved both feed and water restrictions which is not always Industry practice. Water deprivation periods are generally more clearly stated than feed deprivation and curfew periods. On this basis it is likely that some of the farm to slaughter pathways are noncompliant based on NMCOP water deprivation recommendations. Total time off feed can be considerable for all the sheep scenarios cited but they seem compliant with NMCOP recommendations except for the very long transport scenario. However the NMCOP standards do not clearly cite maximum allowable times off feed and is unclear wether this is deliberate or an oversight.

The nature of NMCOP and the differences between states for their implementation suggests that NMCOP could not be uniformly adopted by industry currently for all recommendations. Furthermore there is anecdotal evidence that some recommendations are not being followed. An example is the recommendation in NMCOP slaughter establishments which states that sucker lambs should be killed immediately on arrival at lairage.

Significantly there is very little requirement within NMCOP for monitoring of animal well being during the pre-slaughter period. Welfare outcomes may therefore not be assured even when NMCOP recommendations are satisfied. In a study by (Jacob *et al.*, 2005) it was found that dehydration was prevalent in lamb consignments that had been prepared for slaughter within the time constraints recommended in NMCOP.

Whilst NMCOP are task rather (Transport, Slaughter establishments have different NMCOP) than pathway focussed, communication between relevant parties is encouraged to achieve a pathway outcome. The national vendor declaration scheme provides documentation to allow for communication of curfew times and travelling times between farmer and abattoir managers. However when travel times are not completed in the NVD, an abattoir manager may not be able to determine total time off feed and water prior to lairage. In this case determination of rest period requirements to comply with NMCOP recommendations may be difficult.

7.8.2 Categories for standards described currently by NMCOP standards

7.8.2.1 Facility design

- dimensions of water troughs
- stocking densities
- ramp slopes
- race dimensions

7.8.2.2 Time periods (individual and collective)

- rest
- water deprivation
- feed deprivation
- loading
- transport

7.8.2.3 Livestock handling procedures

- muzzling of dogs
- use of electric prodders

7.8.3 Recommendations for moving sheep

- Dogs transported outside of pens
- Dogs muzzled
- Electric prods not to be used for loading sheep
- Sheep not to be lifted by wool or off ground

7.9 Bibliography

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7.9 Appendices

7.9.1 NMCOP and associated processes

Table 1. National model codes of practice for the welfare of animals relevant to pre-slaughter management of livestock

Short title	Date
Livestock at slaughtering establishments SCARM 79	2001
Land transport of cattle SCARM 77	2002
Land transport of sheep Draft	2004
Land transport of goats (proposed)	
Animals at saleyards SCARM 31	1992

Table 2. Animal welfare legislation within each state

State	Name of Principal Animal Welfare Legislation	Department administering Animal Welfare legislation
Australian Capital Territory		
New South Wales	*Prevention of Cruelty to Animals Act 1979*	Primary Industries
Northern Territory	*Animal Welfare Act 2000 (25)*	Community Development, Sport and Cultural Affairs
Queensland	*Animal Care and Protection Act 2001*	Primary Industries and Fisheries
South Australia	*Prevention of Cruelty to Animals Act 1985*	Environment and Heritage
Tasmania	*Animal Welfare Act 1993*	Primary Industries, Water and Environment
Victoria	*Prevention of Cruelty to Animals Act 1986*	Primary Industries
Western Australia	*Animal Welfare Act 2002*	Local Government and Regional Development
Commonwealth	*Australian Meat and Live-stock Industry Act 1997*	Agriculture, Fisheries and Forestry

Table 3. Government committees involved with NMCOP

Acronym	Membership	Role
PIMC	Primary Industries Ministerial Council (Australian/State/Territory and New Zealand government ministers responsible for agriculture, food, fibre, forestry, fisheries and aquaculture industries/production and rural adjustment policy	Peak government forum for consultation, coordination and, where appropriate, integration of action by governments on primary industries issues. Meets twice per year.
PISC	Primary Industries Standing Committee Departmental Heads/CEOs of relevant Australian/ State/ Territory and New Zealand government agencies, New Guinea is an observer	Supports PIMC
AWWG	Animal welfare working group	Committee responsible to PISC
LGRDWA	Department of Local Government and Regional Development Government of Western Australia	Administers Animal Welfare Act 2002 and Regulations (WA).
Safemeat	Committee with Industry and government members Secretariat located in Australian Government Department of Agriculture, Fisheries and Forestry, Edmund Barton Building, Canberra	Safe Meat, to ensure that red meat products achieve the highest standards of safety and hygiene from farm to consumer and to provide strategic direction and policy advice to the red meat industry.

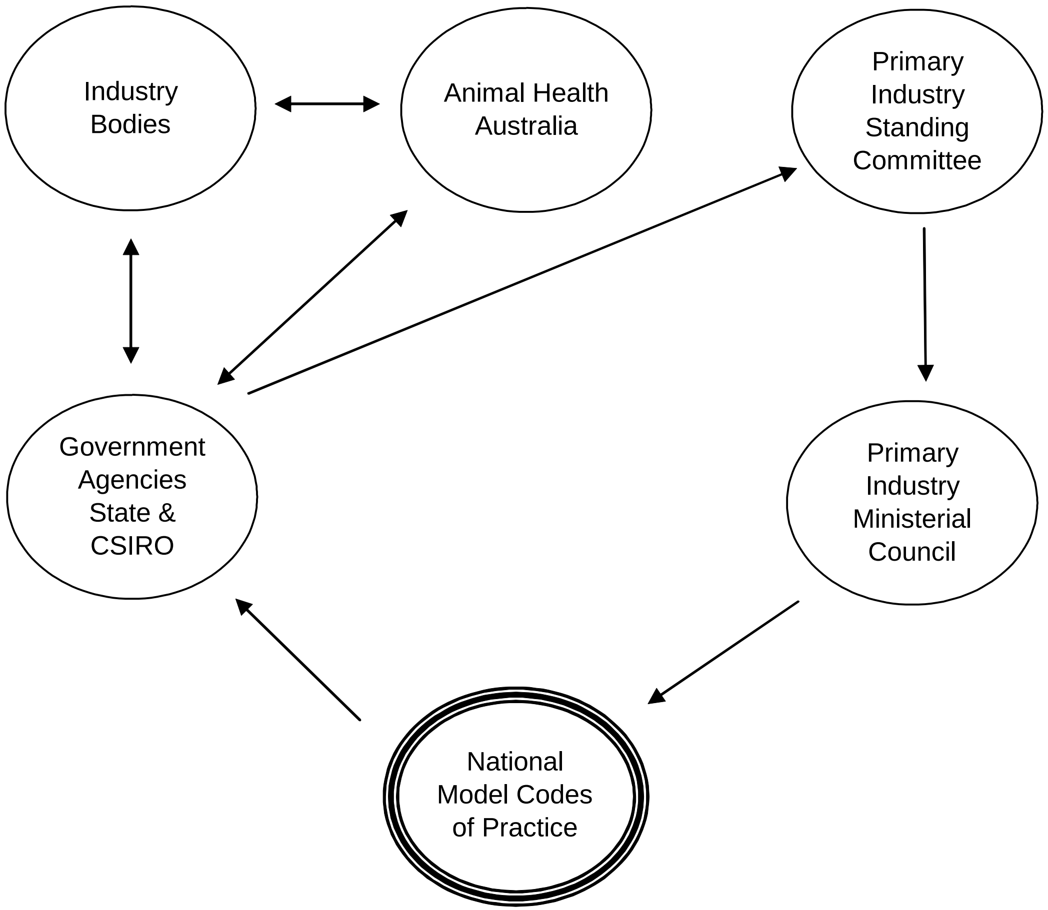

Figure 1. Relationships between government committees, NMCOP and industry

7.9.2 Space and time standards in NMCOP

Table 4. Recommended water trough dimensions (NMCOP saleyards)

Dimension	Recommended length
Length	> 600 mm
Width	> 300mm
Depth	> 300 mm
Stocking density	30 mm/animal for cattle 15 mm/animal for sheep

Table 5. The maximum water deprivation times for cattle including mustering, emptying out, holding, travel and unloading and lairage times (NMCOP cattle transport)

Class of stock	Normal time (h)	Extended time (h)
Mature stock	36	48
Lactating dairy cows	24	No extension
Cows more than 8 months pregnant	8	No extension
Calves less than 1 month travelling without mother	10	No extension
Calves less than 1 month travelling without mother	24	No extension
Calves 1-6 months	24	No extension

Table 6. The maximum water deprivation times for sheep including mustering, emptying out, holding, travel and unloading and lairage times (NMCOP draft land transport of sheep)

Class of stock	Normal time (h)	Extended time (h)
Mature stock	36	38
Young stock (less than 6 months)	20	28
Special classes	12	No extension

Special classes = ewes with lambs at foot, ewes more than 4 months pregnant, drought affected sheep, sheep affected by bush fires

Table 7. Guide to the quantity of water (Vic COP welfare of cattle)

	Quantity of water (l/d)	Maximum total soluble salts (ppm)	Maximum magnesium salts (ppm)
Cows	50	6000	250
Yearlings	40	10000	400
Weaners	25	4000	250

Table 8. Rest periods for sheep

Activity	Time
Prior to transport	1. 24 h for pastoral aerial mustering. 2. Min of 4h if yarded >24 h, or travel > 24 h, or yard+travel > 24 h.
Transport and curfew	1. Adult sheep rest for 12 h every 24hs when transport >24 h 2. Adult sheep (transport + curfew) < than 32 h unless complete in 38h. 3. Special classes < 20h 4. Sheep between weaning and 12 months of age rest for 12hs after 20 hs of transport unless completed within 28h.
Saleyards	Minimum of 2 h, up to 96 h if travel > 24 h
Lairage	Sucker lambs slaughtered asap on arrival Adults minimum of 2h, more if extended transport If transport>24h rest up to 96 h

Rest means unloading, access to food and water and room to exercise and rest.

Table 9. Feed curfews for sheep

Activity	Time
Curfew	0 h (access to dry hay)
Saleyards	<24 h (includes travel and yard time)
Lairage	8-12h prior to slaughter Feed should be offered after 24 h

Table 10. Water curfew periods for sheep

Activity	Time
Curfew	1. At least 8 h (applies to curfew after rest stops during transport as well)
Transport	<24 h unless journey < or= 30 h.
Saleyards	1. 0 h if transport and curfew time >24 h. Or 2. <24 h
Lairage	1. Water on arrival (for 12 h for extended journeys) 2. 12 h off prior to slaughter

Table 11. Rest periods for cattle

Activity	Time
Prior to transport	Rest essential prior to transport 12 h after mustering, 24 h for pastoral country.
Curfew transport and saleyards	<36 h (or max water deprivation period) Cattle older than 6 months spell for 12-24h every 36 h Calves with mother spell for 12-24h every 24 h Calves 1-6 months spell for 12-24h every 24 h Calves 1< months spell every 10 h
Lairage	Minimum 2h Longer if transport long If transport>24h rest up to 96 h

Table 2. Feed curfew periods for cattle

Activity	Time
Curfew	<12 h (access to water not feed)

Table 3. Water curfew periods for cattle

Activity	Time
Curfew	Can restrict 6 h prior to transport

NB Feed is not recommended during water deprivation periods (may exacerbate dehydration).

Table 4. Lambs travelling from eastern wheat belt in Western Australia via saleyards to abattoir on south coast (Time periods are hours) – pathway compliant with NMCOP

Factor	Muster	Curfew	Transport 1	Saleyard	Transport 2	Lairage	Muster + Curfew + Transport 1	Saleyard + Transport 2 + Lairage	Maximum continuous period
Time period	0.5	16	1	24	17	24	17.5	65	82.5
Feed deprivation	0.5	16	1	24	17	24	17.5	65	82.5
Water deprivation	0.5	16	1	0	17	0	17.5	17	17.5
Rest[α]	0	0	0	0	0	0	0	0	0

[α] Rest period

Table 5. Lambs travelling from south east WA direct to abattoir on west coast WA (Time periods are hours) - pathway non compliant with NMCOP for suckers (<6 mo of age) based on water deprivation and 'curfew+transport' component greater than 38 hours. Older lambs compliant.

Time period	Muster	Curfew	Transport	Lairage	Muster + Curfew + Transport	Maximum continuous period
Actual time	0.5	16	17	24	33.5	57.5
Feed deprivation	0.5	16	17	24	33.5	57.5
Water deprivation	0.5	16	17	0	33.5	33.5
Rest[α]	0	0	0	0	0	0

[α] Rest period

Table 6. Adult sheep travelling from central QLD direct to abattoir in South Australia (Time periods are hours) - pathway non compliant with NMCOP based on water deprivation and 'curfew+transport' component greater than 38 hours.

	Muster	Curfew	Transport	Rest	Lairage	Muster + Curfew + Transport	Maximum continuous period
Time period	10	12	36	36	12	58	106
Feed deprivation	10	12	36	0	12	58	58
Water deprivation	10	12	36	0	0	58	58
Rest[α]	0	0	0	36	0	0	36

[α] Rest period

8 Export Livestock.

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Abstract

Stresses associated with fasting and transport of ruminant livestock result in disturbances in rumen function, leading to reductions in dry matter intake (DMI) for periods of from 3-14 d with accompanying weight losses which can range from 4-14%. The pattern of weight loss is usually curvilinear, most occurring during the first 12 hours due to gut, urine and body water losses. Better quality diets are important for appetite and weight regain to occur quickly after transport to registered premises, and before embarkation of exported livestock. Health problems such as Salmonellosis in sheep and goats, influenced by inappetence, are probably exacerbated by fasting and transport stresses. General conclusions are that provided animals at registered premises are provided with reasonable quality diets for about 5-7 days before embarkation to allow recovery, they can tolerate feed and water deprivation associated with transport of up to about 48 hours (cattle) and about 32 hours (sheep and goats), without long term impacts on appetite and weight stasis.

Executive Summary

- There are few specific studies on the impacts of curfew times and transport on livestock destined for export. Consequently, this report draws heavily on more generic reports of these impacts on appetite and weight changes, ruminal function and aspects of animal health in animals curfewed and transported between locations, or consigned for slaughter.
- Stresses associated with fasting and transport result in reductions in dry matter intake (DMI) for periods of from 3-14 d under the most stressful scenarios, these reductions also being accompanied by weight losses. The pattern of weight loss in cattle and sheep is consistent between reports, though the variability probably reflects differences in the initial weight of digestive tract contents, and the extent of body water losses, both of which can be influenced by environmental conditions and by genotype.
- Weight losses are usually curvilinear in nature, and depending on the length of water and feed deprivation and duration of transport can range from 4 to 15% of initial weight.
- Much of the weight loss occurs in the first 12 hours due to loss of water through urine, in faeces and from tissue dehydration, all of which are influenced by stress levels. Rehydration for about 3-4 h increases weight, but the proportion of weight compensated is related to the length of the curfew. Sheep appear more tolerant of water deprivation than cattle, but dehydration will adversely affect carcass weight in both species.
- Ration quality is also important in weight and DMI re-establishment. Better quality diets in the period immediately after transport are important for appetite and weight regain to occur quickly after arrival at registered premises, and before embarkation.
- For sheep and cattle, general conclusions are that the primary effects of feed and water deprivation and transport are reductions in rumen fermentation patterns due to changes in ruminal microflora, decreased ruminal fluid volumes associated with increased water loss, reduced rumen motility and changes in rate of passage and retention time of ingesta. While comparable

information could not be located, it is likely that similar conclusions would apply for goats.

- Some of these concepts have been queried, and further work is needed to clarify these discrepancies.
- Salmonellosis can be an important disease affecting transported sheep and goats, the most important predisposing factor being inappetance in animals before and during sea transport.
- In cattle, health problems due to the BRD complex do not appear to be critical in animals on long haul voyages from Australia.
- The importance of shedding of entero-pathogens such as *E.Coli* by cattle appears to be increasing, but suggestions for nutritional management control techniques need to be further investigated.
- It is concluded that provided animals are held in registered premises on reasonable quality diets for about 5-7 days before embarkation to allow recovery, they can tolerate feed and water deprivation associated with transport of up to about 48 hours (cattle) and about 32 hours (sheep and goats), without long term impacts on appetite and weight stasis.

8.2 Introduction

For exported livestock, there are a limited number of specific reports on the effects of transport and/or curfew times (deprivation of feed and water) on appetite and weight changes, on rumen function and on animal health issues. Similarly, with the exception of a few studies, (Cole and Hutcheson 1981) feed and water curfews have not been investigated separately, though water intake will be reduced if feed is restricted (Cole and Hutcheson 1985a,b).

Thus the approach adopted here in relation to animals for export has been a generalist one, using information and some principles derived from studies of transport and/or curfew time on animals either relocated to other properties or feedlots, or sent for slaughter. Some anecdotal information on transport and/or curfew times is available which is briefly mentioned. While Australian and European data is available on curfew and transport effects on very young calves (usually of dairy origin), this information is not included here, since such animals are a very minor component of the Australian export cattle industry.

Livestock sourced for export undergo a variety of stressors during on-property mustering and yarding, while in transit to and at pre-embarkation assembly depots, and in transit to and embarkation for sea voyages. In general terms these stressors can be grouped into two broad categories of psychological stresses such as fear resulting from handling and restraint, commingling with strange animals, or novel exposure such as noise and transport (Arthington et al 2003), and physical stresses such as hunger, water deprivation, injury, disease and environmental stresses (Grandin 1997).

Definitions relevant to the project on animals destined for export in relation to '*curfew' or 'empty-out'* time, and *'water deprivation'* time are drawn from the Australian Standards for the Export of Livestock, Version 1 (2005), Standards 1, 2 and 3 (DAFF 2005 a,b,c), and are defined in DAFF (2005b, Appendix 2.1; 2005c) as follows:

Registered premises are those premises used for holding and assembling of animals for export, or the pre-export quarantine or isolation of livestock for export. They must be located not more than 8h journey time from the port of embarkation. Specifications on livestock handling facilities and sheds, drainage, environmental protection, fencing and isolation requirements are outlined (DAFF 2005, a,b,c; Sections S3.1 - 3.6) together with minimum standards for management of livestock (S3.8 – S 3.17).

This section of the literature review covers the effects of curfew/transport time on ability to regain appetite and on weight stasis/gain, on rumen function, and on animal health issues when animals are assembled for live export in registered premises. A final section briefly summarises the current legislative requirements in relation to pathways for transport and handling of animals destined for export by sea.

A differentiation has been made in reporting information from overseas studies and those from Australia. Much of the information from Europe (Tarrant 1990; Broom et al 1996; Parrott et al 1998; Knowles 1999) and North America (Tennesssen et al 1984; Kannan et al 2000, 2002; Arthington et al 2003) has involved relatively small numbers of animals, different classes or genotypes of animals, different environmental conditions frequently involving the use of different types of road transport vehicles, and usually involving different curfew times and shorter transit periods.

Because of these potentially confounding factors, caution is needed in transposing these results to Australian scenarios. For ease of presentation and discussion, the data for the first section of the review is presented on a species specific/geographical region basis.

8.3 Effects of curfew/transport time on ability to regain appetite and on weight stasis/gain of export livestock

Level of appetite and weight loss during and after transport results from a combination of effects due to feed and water deprivation, dehydration, mobilization of body reserves, and a range of non specific stress responses mediated by increased pituitary adrenocorticotrophic hormone (ACTH) release which in turn increases adrenal cortisol release (Phillips et al 1991, Fell and Shutt 1986).

There is general agreement (eg Phillips et al 1985; Cole 1995) that curfewing animals can result in substantial weight loss, much of which appears to be due to a loss of water. During the initial period of feed and water deprivation in cattle, the majority of this loss comes from loss of water and dry matter in gut contents and through urination (Shorthose 1980). The extent of these losses, and the time taken to compensate will depend on the duration of the feed and water deprivation, and animals subjected to curfews/transport can have low feed intakes for from 1-3 weeks afterwards. For all species, typically the pattern of liveweight loss is curvilinear, but sometimes these have been linear, and recovery patterns are usually of a similar type. Animal factors including genotype, initial liveweight, condition score and feed type (Thompson et al 1987, Greenwod et al 2006) may also influence the rate of weight loss due to water and feed deprivation. Fasting also depresses water intake so that the hydration status of the animal is affected. However, provided the period without water is relatively short, the metabolic effects of depriving animals of feed and water do not differ much from those of feed deprivation alone (Shorthose and Wythes 1988).

For animals entering registered premises prior to embarkation for export, weight regain is important, but of more importance is resumption of normal levels of dry matter intake (DMI) as soon as possible after arrival to assist in resumption of ruminal function and the regeneration of glycogen reserves. There is general consensus in the literature that at least several days in a feedlot situation are required for this to occur in all species.

8.3.1 Cattle - overseas studies

Cole and Hutcheson (1981) in the US found that in small numbers of steers subjected to two periods of feed and water deprivation of either 24 or 48 h, animals fed hay lost more weight, but feed and water intakes and weight were regained more rapidly than by those on a concentrate diet. In a subsequent study (Cole and Hutcheson 1985a) calves fed high roughage diets returned to pre-fast feed and energy intakes more slowly than those fed medium roughage diets. It was concluded that rumen fermentative capacity was one of the factors influencing feed intake in animals for 7-14d after fasting. An additional study (Cole and Hutcheson 1985b) also confirmed that DMI during the re-alimentation period was positively related to intakes during the prefast period, suggesting that increased prefast feed intake would result in a shorter postfast adaptation period.

In another US study, Phillips et al (1991) examined the effects of fasting alone or fasting and transport (48h) on the amount and source of weight loss in feeder steers. Faecal and urinary excretions accounted for between 38% and 65% of weight loss in two separate experiments, and weight loss associated with fasting plus transport was no different to that due to fasting alone. While both treatments caused mobilization of body nutrients and loss of body weight, these effects were quickly reversed during the post-stress period.

A later study in Florida (Arthington et al 2003), involving two experiments with recently weaned Brahman cross calves sourced from different herds, examined effects of mixing of groups with or without transport for 3h. Weight loss was greater in transported calves but mixing of groups had no effect, nor was there an effect of transport on DMI, which progressively increased over time. There also do not appear to be gender differences between bulls and steers in weight loss due to transport (Tennessen et al 1984).

A number of European studies, most of which have involved relatively short periods of transport by Australian standards, have examined impacts of duration of transport on weight loss. Tarrant (1990) in a review of road transportation of cattle, concluded that even under good conditions of transport, cattle manifest some behavioural and physiological changes indicative of stress. These were not necessarily signs of distress, but may represent normal adaptation to new and uncertain situations, the impacts of which can be minimized by good management, the use of suitable equipment, and attention to good practice in feeding watering and resting cattle on arrival at destinations.

In a UK study involving small numbers of steers transported by road for 5, 10 or 15 h, weight losses were 4.6, 6.5 and 7.0% respectively, recovery to pre-transport weights taking five days (Warriss et al 1995). There was little evidence, based on a range of blood composition parameters, that journeys of 15 h were more stressful than those of 10hours, and the conclusion was that the longer transport period was acceptable from an animal welfare viewpoint. A subsequent study by the same group (Knowles et al 1999) extended this work to cover transport times ranging from 14-31 hours, including a rest and drink stop. The physiological measurements indicated that a journey lasting 31 h was not excessively physically demanding, and that a lairage of 24 h with hay and water available allowed a substantial, but not complete, recovery.

In South Africa, in a study involving a long fast period off feed but not water of 72 h, Van Der Walt et al (1993) concluded that feed deprivation for up to 72h was not a major stressor in cattle entering a feedlot.

Bass and Duganzich (1980) in a New Zealand study found weight losses after water and food deprivation of 17, 24, 41 and 48 h to be 9.4%, 10.7%, 10.0% and 10.5% respectively, most losses occurring in the first 24 h. In animals slaughtered at 17 h, there was a weight loss from the rumen of 41% of dry matter and 27% of water, but loss of intestinal contents was only 14%. About 40% of the weight loss in animals killed at 48 h could be accounted for from losses from the digestive tract. In a subsequent New Zealand study, Gregory et al (2000) found no differences in a range of pre-transport nutritional treatments on weight loss during transport and before slaughter, though there were other advantages such as reduced *E.coli* and faecal excretion levels with less hide soiling.

8.3.2 Cattle - Australian studies

Most relevant work on the effects of transport and curfew times in Australian export cattle comes from studies done in Queensland during the 1980s, mostly undertaken in cattle consigned for slaughter. Shorthose (1980) reported that the extent of weight loss in transit was more closely related to the time animals had been off feed and water than to the length of the journey, and provided summarized information from the literature on the extent of these losses (Table 1).

Wythes et al (1980) found that when animals were fasted (off feed and water), though not transported, most weight loss occurred in the first 12 h and subsequently at a slower, though almost linear, rate to 72h. Weight losses in that study are shown in Table 2, and are within the ranges summarized by Shorthose (1980).

Table 1. Liveweight losses (as percentage of initial liveweight) of cattle deprived of feed and water (after Shorthose 1980).

Time from first weighing (h)	Average liveweight loss %	Range in liveweight loss %
4	3.7	2.0-4.0
8	6.4	3.0-7.2
16	7.8	-
24	8.6	5.0-10.0
48	9.4	6.5-12.0
72	11.5	10.0-14.5

Table 2. Progressive liveweight loss (as percentage of initial liveweight) of Brahman cross steers deprived of feed and water (after Wythes et al 1980).

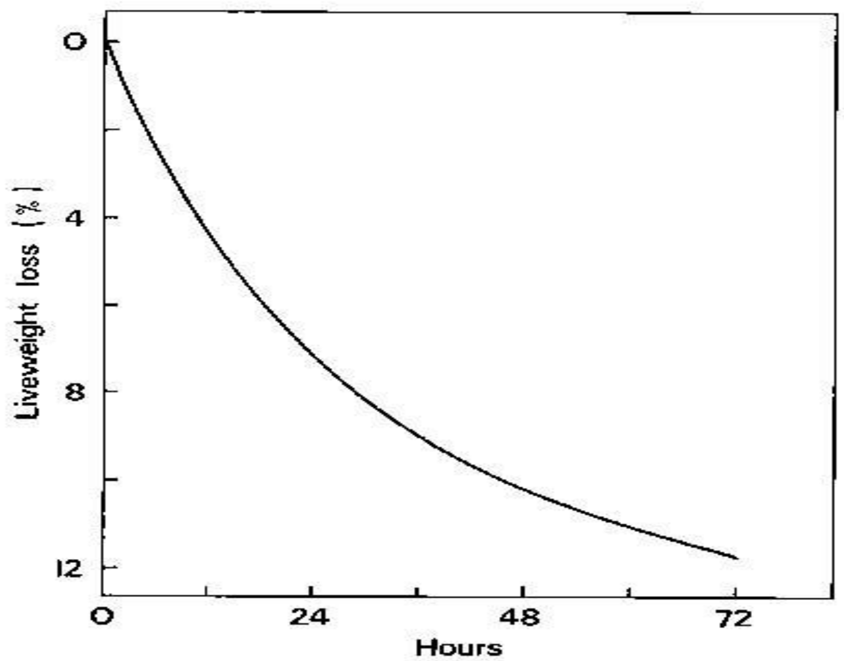
	Time off feed (hours)					
	4	8	12	24	48	72
Loss (%)	2.5	5.0	6.0	7.6	11.4	14.3

The typical rate at which weight loss occurs is shown in Figure 1 (Wythes 1984), patterns which would occur under conditions where cattle are being transported long distances to registered premises for export.

During the first 6 h on water steers recovered weight rapidly, with rate of regain increasing as the length of the fast exceeded 24 h. When steers were provided with feed and water, this further reduced net weight loss in cattle fasted for more than 24h. A later study (Wythes et al 1981) examined weight losses in cows transported to abattoirs over distances ranging from 400-2055km. Losses in transit ranged from 9.4-11.2%, within the ranges quoted above.

In the case of cattle being transported to registered premises prior to export, distances travelled would be within the ranges reported by Wythes et al (1981), suggesting that weight losses would be of similar magnitudes.

Figure 1: A typical rate of liveweight loss for cattle deprived of feed and water.



There is limited Australian information on patterns of feed intake following curfew and /or transport. Parker et al (2003 a,b, 2004) in studies with *Bos indicus* steers found that dry matter intake (DMI) decreased during water deprivation for 90h by about 40% for water deprived animals, compared to declines of about 10% in those provided with water. This agrees with the conclusions of Cole and Hutcheson

(1985b) mentioned previously, that *ad lib* consumption of feed and water before fasting and/or transport results in a shorter postfast adaptation period. There is also anecdotal evidence from Northern Australia (B Leishman, pers comm.) that a period of rest, with access for at least 48 h to ad lib water and forage, prepares recently mustered cattle better for long road journeys of up to 36 h. Experience suggests that these animals regain weight faster and are more easily handled than animals transported directly to registered premises after mustering.

8.3.3 Sheep - overseas studies

Most of the data on feed intake patterns and weight loss in sheep following fasting and/or transport have been from European studies, and relatively little Australian information was noted. Further, much of the European work, frequently involving only small numbers of animals, has been related to measurements of biochemical, physiological and behavioural traits, with limited data on effects on feed intake and weight changes. Knowles et al (1995) noted that in sheep transported for periods ranging from 3-24 h, weight loss increased with time of transport, similar conclusions being reported in a subsequent report (Knowles et al 1996). Hall et al (1997) found that after 14 h confinement (but no transport) sheep had lost 5.7% of initial weight, but there was little recovery of this loss after 1 h of food and water availability. This was similar to results reported by Broom et al (1996), where weight loss in sheep either put on stationary trucks or transported for 15 h was similar (3.6% *v* 5.5%). These authors suggested that water and feed deprivation, and changes in metabolism, rather than stress related effects were responsible for the weight loss during transit. In another study (Parrott et al 1998), where shorn or fleeced sheep were transported for 31 h, with a short feed and water rest period, there were no differences in weight loss between shorn or fleeced sheep, though water intake at completion of transport was markedly reduced in both groups.

This latter point may be of some relevance for sheep being exported from Australia, since in order to meet export standards many wooly sheep are shorn at registered premises before entering the feedlot and/or before embarkation, and fleece cover may not influence weight loss or perhaps DMI during transport.

8.3.4 Sheep - Australian studies

Under Australian conditions some sheep being transported for export from property of origin to registered premises could be in transit for periods up to 32h, and weight losses could be expected to be in the general ranges reported by Shorthose (1980) and Shorthose and Wythes (1988). R Jacob (pers comm.) has indicated that most Australian work on sheep carcase weight loss indicates that loss is at a rate of about 0.1% per hour after fasting and/or transport. Limited data on the effects of water deprivation suggests that water curfews may not reduce urination in the short term, and may increase it if there is significant stress (Parker et al 2003a). In abattoir work in Western Australia & Victoria, Jacob et al (2006) found evidence of dehydration in about half of all lambs, the reduction in carcass weight also probably reflecting a loss of liveweight.

Norris et al (1992) found no significant differences in the proportions of non-feeding adult wethers which had been lot fed for 13, 8 or 3 days before a simulated voyage of 18 days, nor were there any differences in weight losses between the groups. In this study weight loss approximated 20% from farm gate to 18 days, but this may have reflected a sub-maintenance level of feed offered. These findings are also consistent with other studies showing that most feedlot non-feeders begin eating pelleted feed aboard ship (Norris et al 1989 a, b; Norris et al 1990). These authors have suggested as a result that it is not practicable to detect non-feeders in the feedlot and withhold these from export.

Norris et al (1990) and Higgs et al (1991) have indicated that some sheep are predisposed to persistent inappetence and subsequent higher mortality by factors operating on the farm of origin. The latter authors have concluded that while mortality rates between years are similar for sheep from the same farm, there is a relationship of higher mortality rates in sheep from some areas of Western Australia with a longer pasture-growing season, which is also consistent with other studies relating season and fatness as factors relating to mortality (Higgs et al 1991). However the contribution of other factors such as length of feed and water deprivation, and/or duration of transport on weight loss and re-establishment of normal DMI remains unclear in relation to these locational and farm of origin effects.

8.3.5 Goats - overseas studies

In the southern USA during summer, mean weight losses in Spanish goats following transport (2.5 h) and resting for 18 h without feed but with ad lib access to water were 10% Kannan et al (2000). In a subsequent study, Kannan et al (2002) examined the duration of feed deprivation on weight loss in similar goats either deprived of feed or fed for 7, 14 or 21h. Weight loss increased steadily over time, being 7% after 21 h. These authors concluded that, based on changes in a range of physiological indicators (cortisol, glucose, leptin, creatine kinase, plasma urea nitrogen), stress responses begin decreasing within 3 h of transportation. These findings are supported by some Australian data of post-transport declines in salivary and plasma cortisol levels within 1 h in Saanen goats (Greenwood and Shutt 1992).

8.3.6 Goats - Australian studies

Currently, a high proportion of goats exported from Australia are of feral or semi-domesticated feral origin, many of which experience significant stresses from time of capture until embarkation (More and Brightling 2003, Entwistle and Jephcott 2005). There is limited published evidence on weight losses in this type of animal under Australian conditions. Gherardi and Johnson (1994) reported that the failure of goats to eat in feedlots was likely to be the main reason for their poor performance during shipping, and showed that mortalities were higher in goats not eating immediately prior to shipping which had lost more than 20% of initial weight, compared to those eating. The proportion of non-eaters was reduced by increasing the period of lot-feeding from 7 to 14 days, though even then, the proportion of non-feeders was unacceptably high. A subsequent study (Gherardi and Johnson 1995) found that neither pellet composition nor the method of introduction of pellets to the diet affected the performance of feral goats and it was suggested that early screening of non-feeders and their separation should be done to minimize mortalities. Interestingly this recommendation is at variance with conclusions from a sheep study already mentioned (Norris et al 1990) where pre-embarkation identification and removal of non-feeders did not influence the numbers resuming feeding activity on-board ship.

In extensive studies in southern Australia with young domesticated feral goats of about 14kg, Greenwood (pers comm.) found weight losses of 5.9, 7.5, 10.8, and 14.1% at 12, 24, 48 and 72 h after commencement of fasting. Similar magnitudes of weight loss could be expected in domesticated and semi-domesticated feral goats being sourced for export, though most such animals are exported at heavier weights.

8.3.7 Summary

Stresses associated with fasting and transport result in reductions in DMI for periods of from 3-14 d under the most stressful scenarios. These reductions in DMI are accompanied by loss of weight. Although the pattern of weight loss in cattle and sheep is consistent between reports, the variability probably reflects differences in the initial weight of contents of the digestive tract, in and in the extent of body water losses. These can be influenced by environmental conditions and by genotype. Much of the weight loss occurs in the first 12 hours due to loss of water through urine, in faeces and from tissue dehydration, all of which are influenced by stress levels. Rehydration for about 3-4 h increases weight, but the proportion of weight compensated is related to the length of the curfew. Sheep appear more tolerant of water deprivation than cattle, but dehydration will adversely affect carcass weight in both species.

Ration quality is also important in weight and intake re-establishment. Extensive experience with Australian feedlot cattle indicates the importance of high quality diets in the period immediately after feedlot entry in order for animals to quickly regain appetite and weight gain.

These findings have implications in the transport of export cattle, sheep and goats from property of source to registered premises, and their subsequent recovery patterns whilst there, and before embarkation. However it is concluded that provided animals are held in registered premises on reasonable quality diets for about 5-7 days before embarkation to allow recovery, they can tolerate feed and water deprivation associated with transport of up to about 48 hours (cattle) and about 32 hours (sheep and goats), without long term impacts on appetite and weight stasis.

8.4 The effects of curfew/transport time on rumen function and subsequent implications for regaining appetite and weight stasis /gain.

Alterations in rumen function occur when rapid dietary changes are imposed eg from a grazing situation to a feed lot situation, and rapid resumption of appetite is needed to ensure a maintenance or above maintenance DMI is achieved to minimize weight loss, and the effects of a range of stressors.

As for the previous section**,** there are few specific reports in relation to exported livestock of the effects of transport and/or curfew times (deprivation of feed and water) on rumen function and subsequent implications for regaining appetite and weight changes. Fasting has an immediate effect on ruminal microbial populations and activity, and ruminal fermentation is progressively reduced. The following section reviews some of the fundamental changes occurring following transport or imposition of curfews.

A number of studies have examined the effects of feed and water deprivation on ruminal function in cattle (Galyean et al 1981; Cole et al 1985a,b ; Fluharty et al 1996; Loerch and Fluharty 1999) and in sheep (Cole 1995, 2000) but similar work in goats could not be located. Summarised information on ruminal VFA changes at different times after fasting, or at different feed intake levels is shown in Figures 2 and 3 of Appendix 1. Galyean et al (1981) found that ruminal protozoal and bacterial concentrations did not return to pre-fast levels until 104 hours after a period of 32 h of feed and water deprivation with or without transport. In this study, both ruminal protozoal and bacterial counts were depressed to a greater extent in transported than in fasted groups, and rumen pH also increased as a result of fasting and transport.

Cole and Hutcheson (1981) found that ruminal fermentative capacity as measured by *in-vitro* gas production was still below pre-fast levels 5 d after a 48 h fast. In a later study in steers (Cole and Hutcheson 1985a), ruminal fermentative capacity appeared to be the most important factor limiting DMI for 7-14 d after a period of feed and water deprivation.

Based on ruminal volatile fatty acid (VFA) changes, Galyean et al (1981) have suggested that rumen motility may be more impaired when animals are both fasted and transported than just fasted, and fasting significantly reduces ruminal contractions and the rate of passage of digesta through the gut (Cole et al 1986). These latter authors also compared the effects of fasting *vs* transport (13h ; 46 h) on steers fed either roughage or concentrate based diets. Transported steers lost more water than fasted steers, losses which would also have been associated with greater electrolyte losses, and these animals also had greater urinary, faecal and total nitrogen (N) losses. In a second longer (46h) trial there was no difference in ruminal fluid volumes between fasted and transported groups, and while total ruminal VFA concentrations declined, there were no differences between the groups.

In a more recent review of a considerable body of earlier work on the effects of transport and feed and water deprivation on newly received feedlot cattle, Fluharty et al (1996) and Loerch and Fluharty (1999) concluded that feed and water deprivation coupled with trucking had no effect on ruminal bacterial populations, or on ruminal fermentative capacity, though ruminal protozoal numbers (see Figure 4 of Appendix 1), ruminal volume and weight of rumen contents decreased as duration of feed deprivation increased, changes which were related to a reduction in DMI.

These discrepancies could well be a reflection of the limitations of the two different techniques used in the earlier and later studies for monitoring ruminal microbial activity. This discrepancy needs to be resolved however, because in an export livestock scenario, it is important that a high DMI is achieved as soon as possible after curfew/transport, and while animals are in registered premises and before embarkation.

There is some evidence from Bos indicus cattle (Musimba et al 1987) of rate of passage and retention time of digesta, in addition to being related to forage intake and digestibility, are also related to frequency of drinking. Decreased particle passage rate, but increased mean retention time occurred as frequency of water intake increased from once daily to once in 3 days. These changes were also associated with a reduction in DMI with increasing watering intervals, supporting earlier suggestions (Campling 1970) that the rate of digesta disappearance from the reticulorumen influences DMI, which in turn can also be influenced by water restrictions, a situation which occurs with long distance transport.

Dehydration associated with fasting and transport could alter body water and electrolyte distribution (McFarlane and Howard 1969), and Cole (1995, 2000) has suggested that in partially dehydrated sheep, abnormal water and electrolyte shifts may be factors contributing to decreased feed intake, which could also be voluntarily limited to minimize adverse effects on osmotic balance. Bass and Duganzich (1980) found that in cattle after increasing periods of food and water deprivation there were progressive declines in weight and in DM content of both stomach and intestinal contents, suggesting that a major component in loss of weight during fasting was due to reductions in gut contents and in gut water. Some of these aspects have been covered earlier.

8.4.1 Summary

For sheep and cattle, general conclusions are that the primary effects of transit and associated feed and water deprivation were reductions in rumen fermentation patterns due to changes in ruminal microflora, decreased ruminal fluid volumes associated with increased water loss, reduced rumen motility and changes in rate of passage and retention time of ingesta. Some of these concepts have been queried, and further work is needed to clarify these discrepancies. Whilst comparable information could not be located for goats, it is likely that similar conclusions would apply for this species.

8.5 The effects of curfew/transport time on animal health issues as animals are assembled for live export in pre-export premises

Many aspects of the impacts of transport and/or feed and water deprivation on enteropathogen epidemiology and control are covered in other sections of this project. This aspect is only covered briefly here, particularly in relation to interactions of factors that may influence animal responses to health challenges during export.

Transport and variable periods of feed and water deprivation may stress ruminants, resulting in poor performance, increased disease susceptibility and on occasions high morbidity and mortalities. In animals being exported, multiple stressors occur at all stages along the assembly, transport and pre-embarkation pathways. These are manifested in a number of ways, including transient endocrine responses, impairment or modifications to the immune system, alterations in metabolic processes, in rumen function and digestion and impairment of DMI and weight status (Loerch and Fluharty 1999). Identified stresses, in addition to transport and water and/or feed deprivation, include weaning (Galyean et al 1999) and exposure to a variety of infectious agents. All of these can interact, resulting in decreased DMI and a short term nutritional deficiency (Cole and Hutcheson 1985b) that influences the response to health challenges and in some cases leads to increased pathogen shedding (Galyean et al 1999).

The importance of stress effects on the generic syndrome of transport induced disease is indicated by the fact that there is frequently rapid adrenal gland enlargement in diseases such as ovine *salmonellosis* (Higgs et al 1993), and bovine shipping fever (*Mannheimia haemolytica*) with increased circulating cortisol levels (Frank et al 1983). Young animals appear to be particularly vulnerable to transport stress, since their immune system is naïve and they lack exposure to many stressors that older animals have been exposed to. However there is comparatively little critical information available on the patho-physiology of transport induced disease syndromes and their impacts.

Salmonellosis is the most important infectious disease affecting exported sheep, and can be a major contributor to morbidity and mortality rates both before and after embarkation. The biggest single predisposing factor for *salmonellosis* is inanition or inadequate feed intake (Higgs et al 1993); inappetant sheep (following curfew or transport) having an increased risk of infection and death. Also the proportion of sheep excreting salmonella increases over time in the feedlot and on-board ship (Richards et al 1989) and excretion rates are usually higher in fasting sheep (Grau et al 1969). Where sheep are held at registered premises in raised sheds so that faeces removal occurs, the level of environmental contamination and thus the level of bacterial challenge is reduced, but on-board, sheep pens are not usually cleaned at least within a journey (Higgs et al 1993) and build up of organisms may occur, sometimes with increasing levels of morbidity and mortality.

However other factors than stress alone may also contribute to inanition. Inanition and the risk of *salmonellosis*, may also be related to season, source of origin and metabolic status of sheep, the risk varying between different lines of sheep at different times of the year. In sheep exported from Western Australia fat adult wethers in the latter part of the year are the most vulnerable (Norris et al 1989b, Richards et al 1991, Higgs et al 1991, 1999)

In cattle being transported either by road or by sea, bovine respiratory diseases (BRD) are sometimes a sequela to transport stresses or following holding of cattle under intensive conditions. These conditions can be either of bacterial (principally *Mannheimia (Pasteurella) haemolytica*) or viral (Bovine pestivirus) origin, and there is a good amount of information to indicate that a reduction in immune competency following stress can be a pre-disposing factor to these infections.

The importance of the BRD complex is well recognized in Australian feedlot cattle, and recently released new generation vaccines developed by the Beef CRC against both bacterial (shipping fever) and viral infections are now available to minimise impacts, though the extent of their use in export cattle is difficult to gauge, since there appears to be little critical information on this syndrome in cattle being exported by sea. In the only detailed study undertaken of cattle deaths during sea transport from Australia, Norris et al (2003) found that respiratory disease ranked third in importance after heat stress and trauma as a cause of death. Mortalities due to respiratory disease (diagnosed as probably due to *Mannheimia* infection) accounted for about 17% of all mortalities in four monitored voyages to Middle Eastern ports.

Entero-pathogens of human health consequence are *Salmonella* spp and *Escherica coli.* In lairage (where conditions can be similar to shipboard) animals can become infected and recontaminate the environment and group mates. Faecal excretion of *E.coli* is apparently reduced by feeding roughage prior to transport (Vanselow et al 2005) but this needs to be tested experimentally before general recommendations could be made in relation to exported livestock. A detailed discussion on enteropathogens as they relate to this project is in the section “ Review of food safety and carcase hygiene ‘by Pointon and Kiermeier.

8.5.1 Summary

The health of exported livestock is influenced by a series of complex interactions between the extent of stress caused by transport and/or feed and water deprivation, the level of immune suppression that occurs, the impacts of a short term nutrient deficiency due to reduced intake, age of the animal and the extent of challenge by infectious or toxic agents. Salmonellosis can be an important disease affecting transported sheep and goats, the most important predisposing factor being inappetance in animals before and during sea transport. In cattle, health problems due to the BRD complex do not appear to be critical in animals on long haul voyages to the Middle East, although there is no information on the incidence of BRD in overseas feedlots, post arrival. The importance of shedding of *E.Coli* organisms by cattle appears to be increasing but suggestions for nutritional management control techniques need to be further investigated.

8.6 Pathways for animals destined for export by sea transport.

In relation to export of sheep, cattle and goats, movement pathways cover operations from on-property mustering and yarding, through land transport from property of origin to:

- temporary holding/resting areas then
- to registered holding premises, then
- to point of embarkation at wharf or airfield

Guiding principles and required outcomes for each of these stages of operations for cattle and for sheep are outlined in Anon (1999, 2005) and the Australian Standards for the Export of Livestock, Version 1 (2005), Standards 1, 2 and 3 (DAFF 2005 a,b,c). Vessel loading and livestock management on-board principles and required outcomes are outlined in Standards 4 and 5 (DAFF 2005 d,e), while the sourcing of livestock for export by air and their on-farm preparation is covered in Standard 6-Air Transport of Livestock (DAFF 2005 f).

In addition to these specified curfew, water deprivation and rest period times, there are also a range of conditions which could impact on health and well-being during transport or export preparation, which are outlined for each species in the Standards, 1, 2 and 3 (DAFF 2005 a,b,c). These include requirements for identification by property of origin (in the case of sheep where disease testing is required also on an individual basis), weight and condition status, and, in the case of breeding females, pregnancy status. Feeding levels and types of feed are also specified, and in the case of feral goats there are also requirements for handling and training.

The pathways for, and current curfew, water deprivation and rest period times, and any specific handling requirements, are summarized in the following flow diagrams in Appendix 1 for cattle and buffalo (Figure 5), sheep and lambs (Figure 6) and goats (Figure 7), drawn from DAFF 2005 a,b,c.

8.7 Bibliography

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8.8 Appendices

Figure 2.Total ruminal VFA levels (mMol/L) at 0, 3 and 10 days after feed and water deprivation of steers on 3 intake levels (Cole and Hutcheson 1985b)

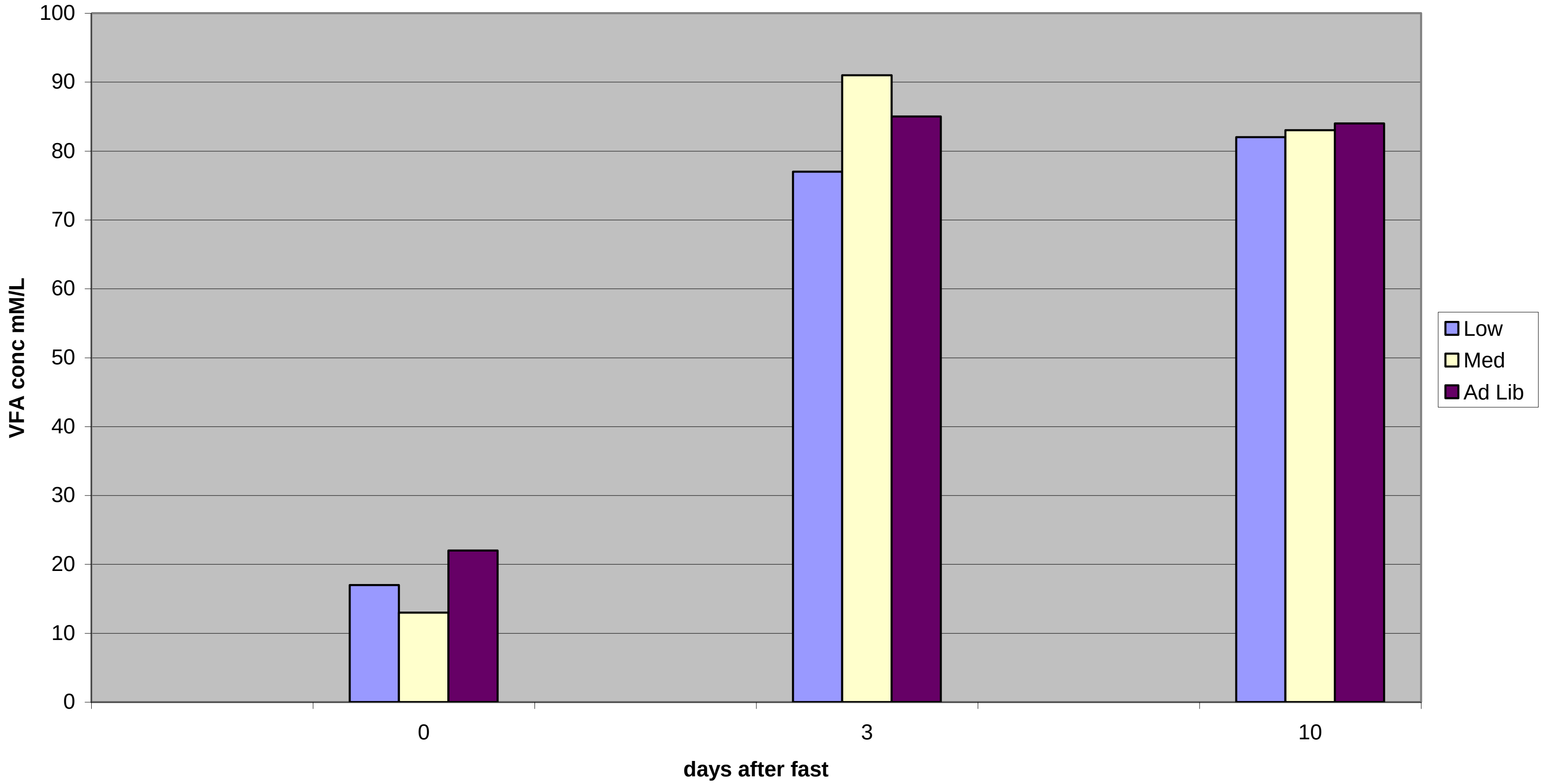


Figure 3. Total VFA concentrations (mmole/L) at hours after fasting or fasting + transport of beef steers (Galyean et al 1981)

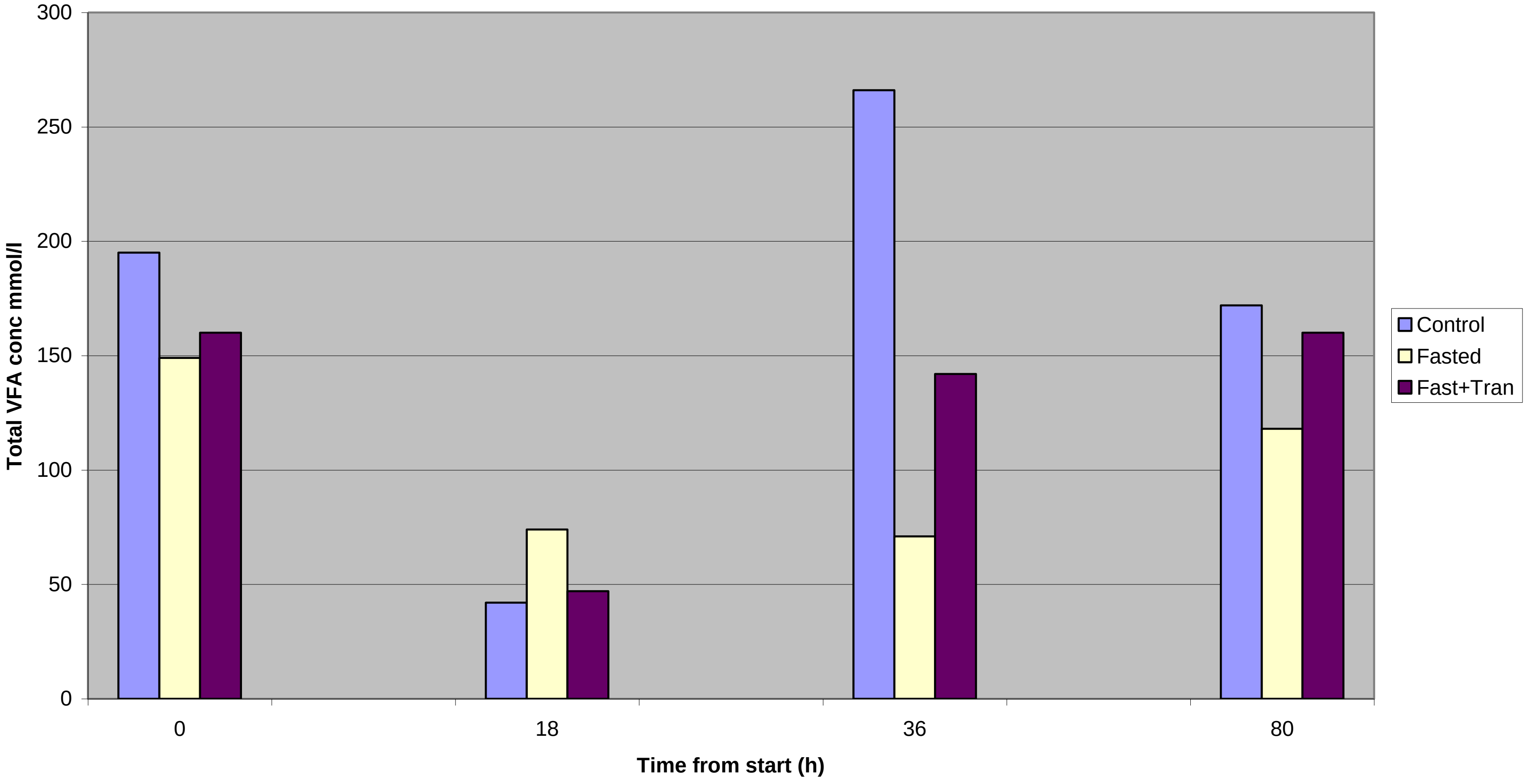


Figure 4. Effects of 0, 48 or 72 h of feed and water on ruminal protozoal concentrations (nx103/ml) at days 0,4 and 7 after deprivation (Fluharty et al 1996)

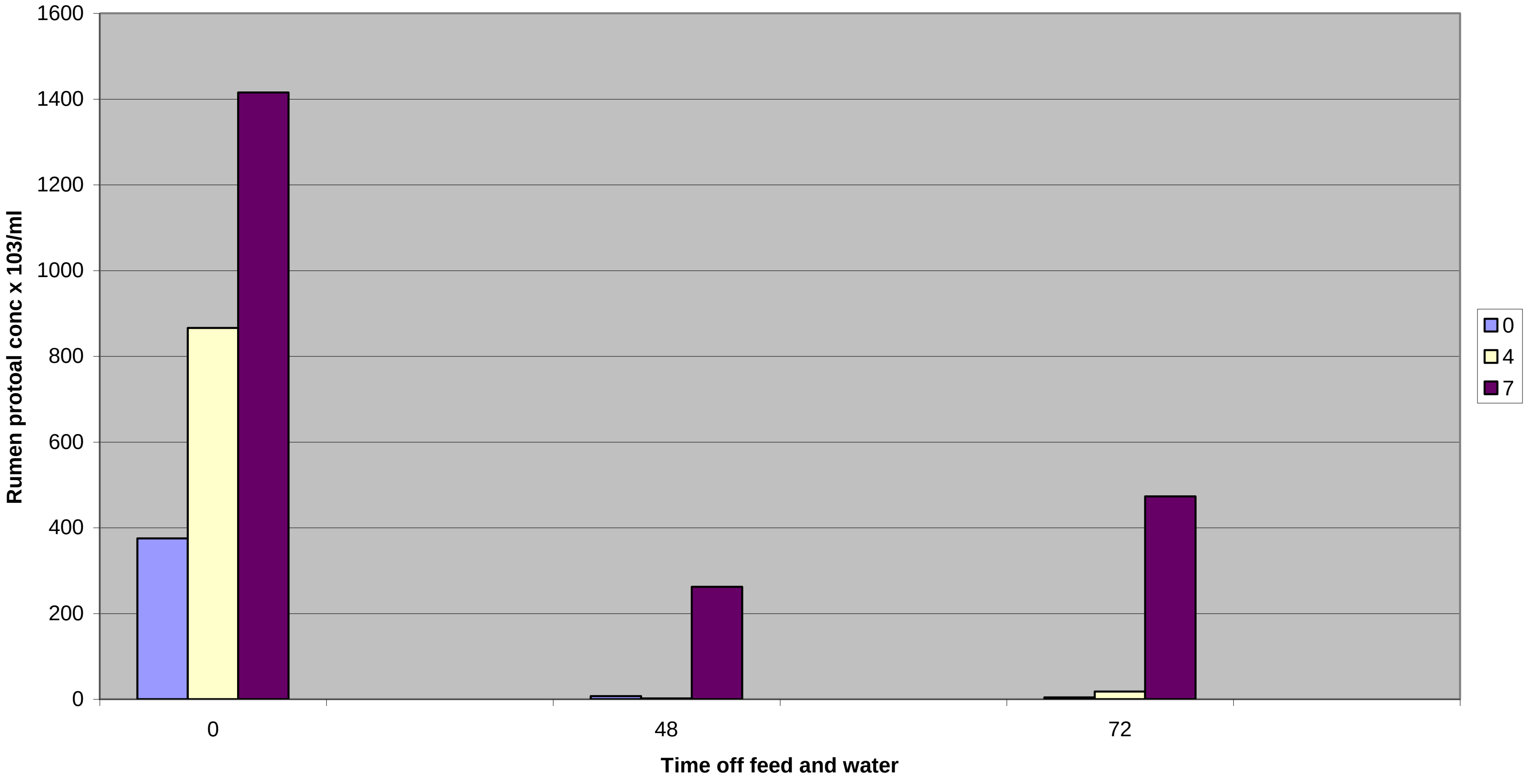


Figure 5. Summary holding, rest, feed and water times for export cattle/ buffalo from property of source to registered premises (interpreted from the National Model Codes of Practice)

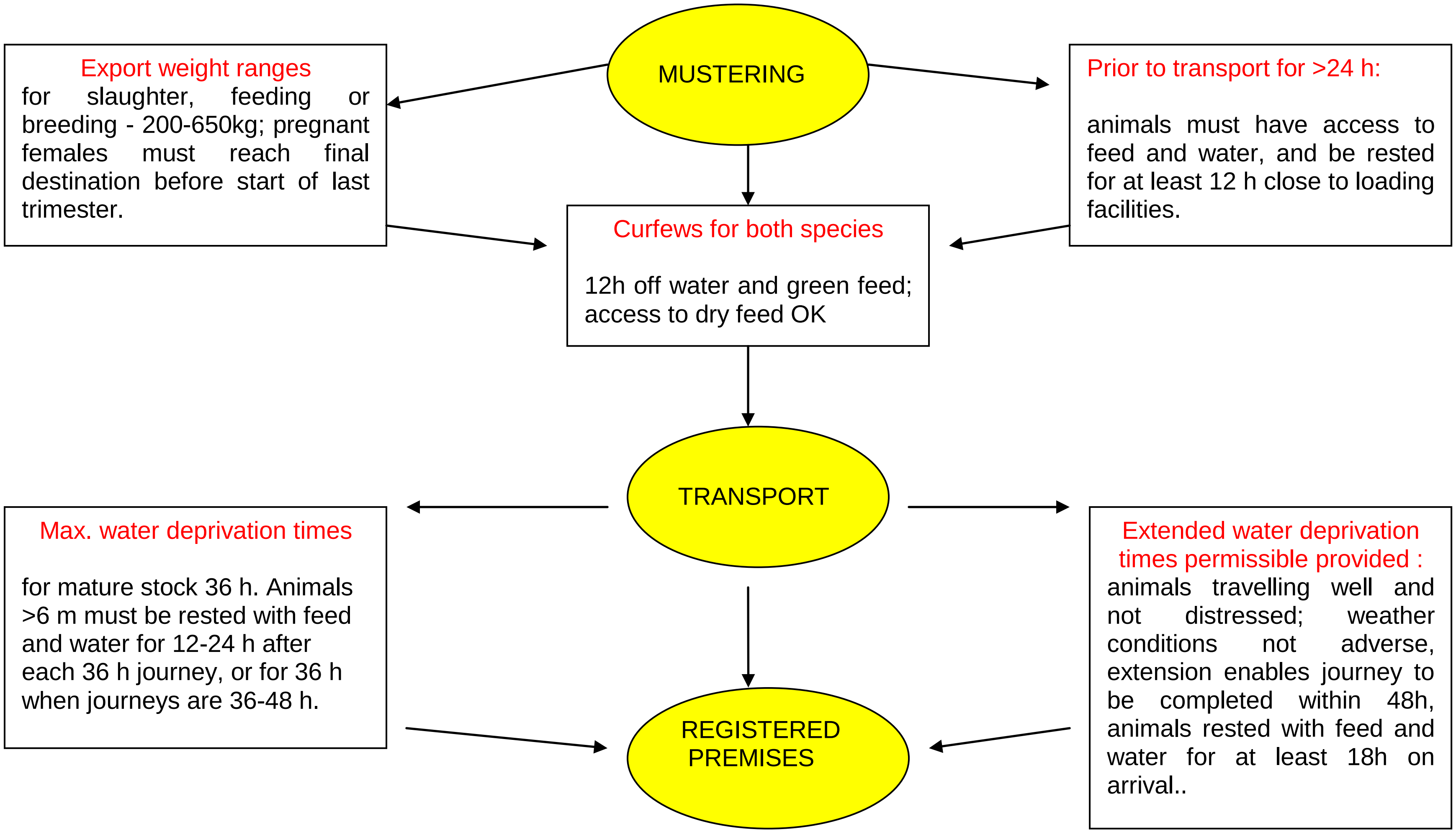


Figure 6. Summary holding, rest, feed and water times for export sheep from property of source to registered premises (interpreted from the National Model Codes of Practice)

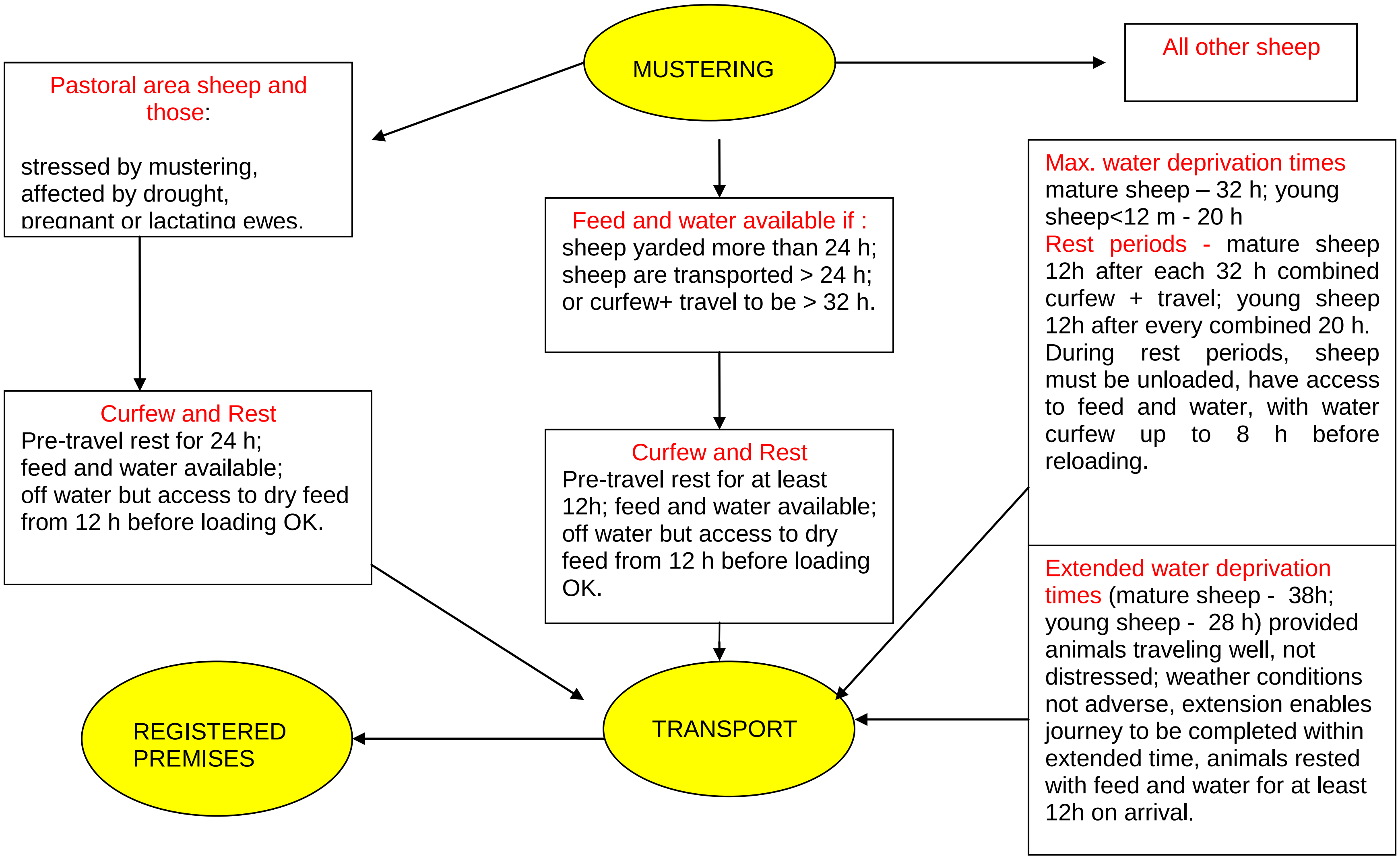
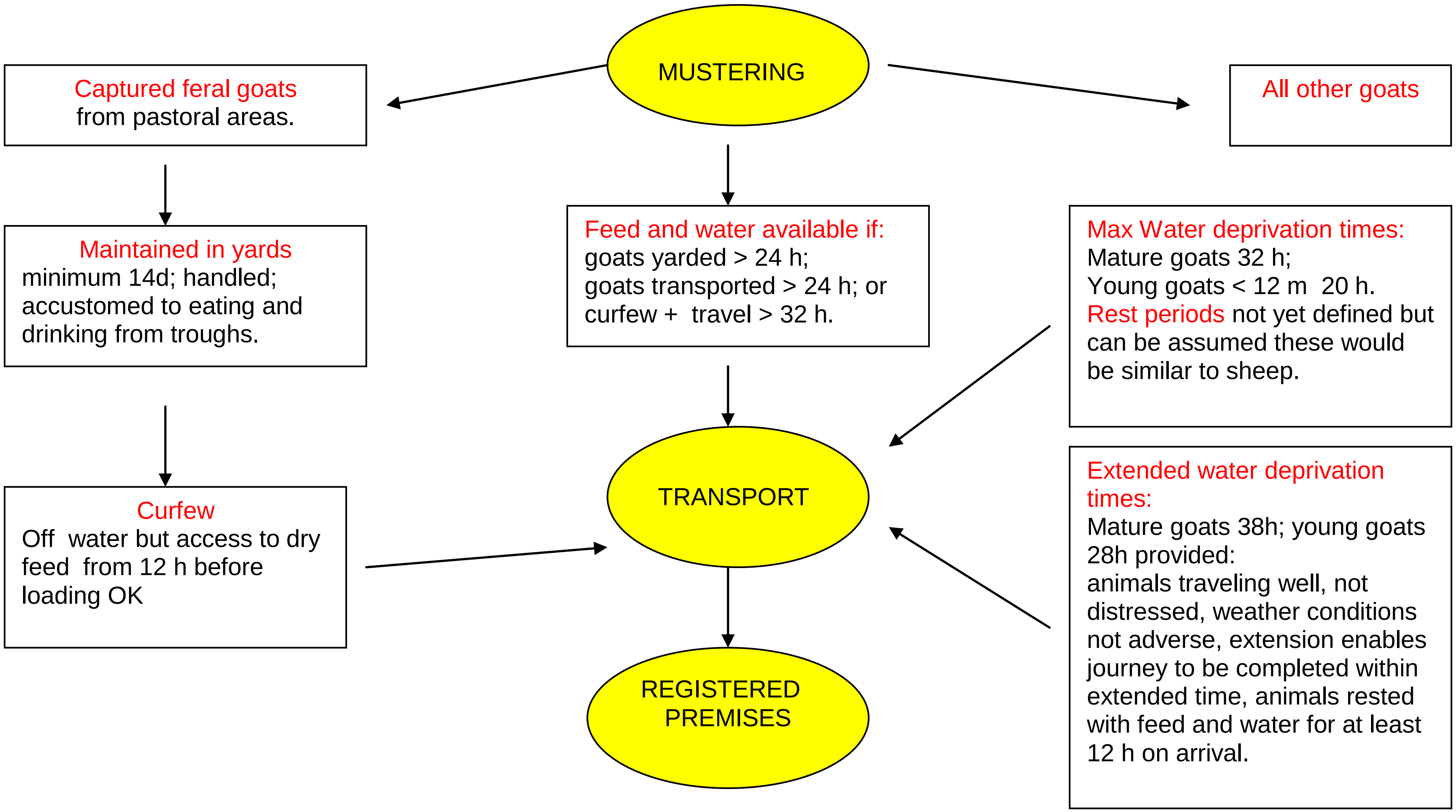


Figure 7. Summary holding, rest, feed and water times for export goats from property of source to registered premises (interpreted from the National Model Codes of Practice)



8.9 Conclusions and Recommendations

Slaughter Curfews

Food Safety

The reviewers agreed that food safety was a crucial factor that would drive the final on farm curfew conclusions and indeed total time off feed/water recommendations.

Food safety has both specific issues such selected pathogens like *E. coli* O157:H7 and *Salmonella* spp. and more general issues which are under pinned by carcase hygiene indicator organisms (i.e. *E. coli* biotype 1). Different markets have different requirements with respect to these issues.

Off-feed and water curfew is practiced on-farm to reduce soiling during transport and optimise hide/fleece cleanliness at slaughter. However in microbial terms it represents only one component of pre-slaughter management that influences microbial status of livestock and their subsequent influence on carcase contamination.

The food safety team concluded that to minimise transmission of pathogens and microbial contaminants during carcase dressing, emphasis should be on clean hides/pelts in livestock presented for slaughter. This will minimise direct contamination to the carcase from hide/pelt filth, and in doing so, reduce potential contamination from faeces containing high levels of hazards resulting from long periods off-feed.

While off-feed curfew reduces the potential for faecal contamination of hides/pelts, the additive effect of increasing time-off-feed (including on-farm curfew) on unwanted microbial growth within the intestines produces a countervailing effect. This clearly applies for both *Salmonella* and generic *E. coli*.

Off-feed curfews prior to transport of up to 24 hours are indicated to minimise soiling of the hide/pelt, which is associated with efficient dressing and lower carcase microbial counts. The total time off feed between the farm – slaughter interval is recommended not to exceed 48 hours due to its effect on unwanted microbial growth within the intestines.

The precise length of the curfew to maintain ‘clean’ stock is a complex equation determined by feed type (affecting soft versus hard faeces), coat/wool length and transport time. There is insufficient scientific data on the proportional contribution of these factors to resolve these issues. However Industry practice in commercial sheep supply chains (in Western Australia) suggest relatively short curfew periods are acceptable to allow carcase hygiene standards to be met (see overall conclusions and Table 2 below).

It is suggested that a “cleanliness” or outcomes-based standard should be supported by the implementation of a hide/pelt scoring system that could be related to the economics of dirty hides/pelts (dressing and microbiological) including feedback of scores and financial penalties to producers. A validated scoring system would then allow companies to undertake research with their clients to optimise the curfew periods rather than relying on conservative ‘blanket’ recommendations.

It cannot be assumed that pre-slaughter controls for generic *E. coli* and *Salmonella* will be effective for *E coli* O157/STEC from either grass or lot-fed production systems. The effect of pre-slaughter controls for sheep carcase hygiene is similarly unreliable. Therefore, greater focus should be on optimal dressing procedures to minimise hazards and the attainment of excellent microbiological status of carcases.

These should receive greater emphasis than pursuing complex pre-slaughter controls that are subject to considerable variation in microbial efficacy, and as such, are unsuitable as Critical Control Points within a HACCP system.

Environmental and Biosecurity

From an environmental perspective, a 24 hour curfew (off-feed) would appear to significantly reduce the manure load released by cattle during transit. Urine load was not considered as a major environmental issue. Reductions of 50% or more in effluent production compared to fully fed controls have been reported in studies of cattle fasted for 24 hours. There are commensurate reductions in excretion of organic and nutrient contaminants, all of which pose environmental risks if spillage occurs in transit, especially in populated areas. There is only marginal additional benefit for longer curfew periods and clearly a need to investigate the efficacy of shorter periods especially given the industry practices in Western Australia cited below. The review also highlighted the limited data available for sheep and lambs.

It was concluded that a curfew of less than 48 hours would have little, if any, mitigating impact on biosecurity risks associated with weed dispersal and disease spread. This essentially implies that curfew plays no role in biosecurity.

Meat quality and carcase yield

The issue of meat quality is largely driven by the need for adequate levels of muscle glycogen at slaughter. Muscle glycogen levels are secured by ensuring good nutrition on farm in the 2 weeks leading up to consignment to enable minimum recommended growth rates (0.8-1kg/day for cattle, 100gm/d for cross bred lambs and 150gm/day for Merino lambs). In addition stress should be minimised during the mustering, curfew and post farm gate segments of the pre-slaughter period. In this sense ‘total time off feed’ is considered the major risk factor rather than the curfew component. Thus muscle glycogen will either stay constant or decline but never increase during the immediate farm to slaughter period. Therefore the curfew period alone is not the issue but more the total time off feed and water. The recommendations are that total time off feed for slaughter cattle and sheep should be no more than 36 and 48 hours respectively and that lairage can be quite short (4 hours) if needed. There is evidence that particularly cross bred lambs are more resilient with respect to glycogen metabolism than yearling cattle. The issue with respect to curfew time is that it can represent a significant component of total time off feed.

Carcase weight losses are associated with food and water deprivation. The carcase weight losses begin to occur after 24 and 12 hours off feed in cattle and sheep respectively. The losses are in the order of 0.1% and 0.04% per hour out to 48 hours for lambs and cattle respectively. Water deprivation alone can reduce carcase weight by 3% and lean meat yield by 4% in lambs. Clearly strategies that allow the time off feed to be reduced or hydration status to be increased will allow more carcase weight and lean meat yield. For example reducing time off feed in slaughter lambs from 48 to 36 hours equates to about 0.24kg of extra carcase weight.

Welfare

This review dealt with the direct effects of food and water deprivation on animal welfare and concluded that based on physiological and metabolic indicators, fasting for 24-48 hours resulted in small but acceptable changes in healthy dry livestock.

Dehydration was cited as the most significant animal welfare concern.

It was concluded that the National Model Codes of Practice for the Land Transportation of Livestock (NMCOP) are appropriate on animal welfare grounds with respect to water deprivation recommendations (36 hours for cattle greater than 6 months of age, 36 hour for sheep greater than 6 months of age and 20 hours for lambs less than 6 months of age with some margin for some extension during very long transport).

Based on typical Industry farm to slaughter pathways the length of the curfew period would break NMCOP recommendations only if water was not made available. However the NMCOP recommendations are unclear with regards to recommendations for total time off feed.

There was insufficient scientific evidence to conclude that pre-transport curfew improves the capacity of ruminants to cope with transport.

It was recommended that there would be value in developing strategies to improve the capacity/willingness of animals to consume water when it was available during lairage and in saleyards.

Overall conclusions

A summary of the different recommendations from each discipline segment is shown in Table 1. The recommendation clearly shows that the curfew period should be 24 hours or less since the vast majority of faeces has been expelled. The maximum time off feed is recommended at typically around 48 hours to comply with food safety, meat quality and welfare recommendations. Importantly any period of reduction in total time off feed below 48 hours would deliver very significant gains in carcase weight and lean meat yield. Accordingly the curfew period should be only enough to allow sufficient faecal expulsion to maintain ‘clean’ livestock after transport. It is likely that this curfew period might be typically less than 24 hours (Table 2).

The manipulation of urine output by imposing water as well as feed based curfews has not been studied scientifically. However the conclusion of the review team was that water curfews would be (i) most likely ineffective in reducing urine loss, (ii) play a minor role as a determinant of clean livestock after transportation and (iii) if imposed, would often mean the farm to slaughter pathway would not comply with NMCOP dehydration standards. However, further work is required to substantiate this conclusion.

Table 1. The recommended time period (hours) off feed or water to maximise each of the disciple segments in livestock destined for slaughter.

Discipline Segment	Feed Curfew	Total time off feed	Water recommendation when not in transport	Total time off water
Food safety	≤ 24 (enough to ensure clean hides/pelts)	≤ 48 (minimise pathogen over growth)	Available	NA[a]
Environmental	≤ 24 (minimise faecal production)	NA	Available	NA
Biosecurity	≥ 48-72 (minimise seed loss in faeces)	NA	Available	NA
Meat quality	NA	cattle ≤ 36 sheep ≤ 48 (minimise dark cutting)	Available	Manage hydration index (urine specific gravity)
Carcase loss	NA	cattle ≤ 24 sheep ≤ 12 (carcase shrink after this time)	Available	Manage hydration index (urine specific gravity)
Welfare	Unknown (effects on transport stress not known)	cattle ≤ 48 sheep ≤ 48	Available	adult cattle ≤ 36[b] adult sheep ≤ 36 young sheep ≤ 20

[a]NA – no recommendation since not relevant

[b]Adult cattle or sheep defined as dry and > 6 months of age. Young sheep defined as lamb < 6 months of age. Recommendations same as NMCOP including special cases for extension.

Evidence that the curfew period can be reduced below the maximum recommended time of 24 hours can be found in industry. For example the Q-lamb alliance regulations on curfew for slaughter lambs (Table 2) recommend relatively short curfews of between 6-12 hours depending on feed type and transport duration.

Table 2. Q-lamb curfew recommendations

Feed type	Transport duration (hours)	Pre-transport curfew recommendation (hours off feed only)
Spring pasture (= suckers mainly)	Short (<4)	6
Spring pasture (= suckers mainly)	Long (>4)	8-12
Dry feed, grain assisted or feedlot (= weaned lambs)	Short (<4)	4-6
Dry feed, grain assisted or feedlot (= weaned lambs)	Long (>4)	8

Another Western Australian lamb supply chain, WAMMCO International, has similar recommendations of between 8-12 hours feed curfew regardless of distance transported. Both supply chains require a feed only curfew with access to water allowed.

Future research – slaughter curfews

Each review has a detailed list of recommended research areas. Below is the consolidated recommendation of the review team for future research:

(i) *(a) The effect of time off feed and water on faecal, urine and E.coli expulsion*

The purpose of this experiment would be to examine in detail the time response of faecal, urine and pathogen expulsion in the 0-24 hour period post fasting. Previous research has not addressed this period.

A suggested experimental design might be:

- 2 species (cattle x sheep)
- 2 levels of hydration (plus/minus water)
- 2 types of feed (lush pasture x dry finishing diet)
- 4 times periods for measurement (0, 6, 12, 18, 24 hours)

Measurements to include numerous faecal and urine parameters. This experiment would best be done using an intensive laboratory design if possible.

(b) Trucking off pasture

There was insufficient scientific evidence to conclude that pre-transport feed curfew improves the capacity of ruminants to cope with transport (i.e. effects on slippage and travel sickness). However it is understood there is currently work being undertaken in cattle to investigate the effects of feed curfew and trucking time in pasture fed cattle. It is recommended that similar work be undertaken is sheep.

A suggested design might be:

- 3 levels of feed curfew (0, 6,12, 24 hours)
- 2 levels of trucking time (5, 15 hours)

However the design would be heavily influenced by the outcomes of experiment (i). Measures to include welfare, dehydration, slippage, pelt score and microbiological data. The aim of experiments described in (i) would be to develop a 'curfew' predictor.

(ii) Economic analysis

An important component in all the research strategies would be an economic analysis. However in addition a general assessment of economic critical control points would be valuable to assess the interacting effects of:

- Market requirement
- Food safety risk
- Carcase shrinkage
- Trucking cost implications
- Abattoir cost implications

(iii) Hide/Pelt scoring system undertaken with Industry

The purpose of this study would be to develop a robust hide/pelt scoring system (for sheep and cattle) which described quantitatively the 'cleanliness' of livestock at slaughter. Such an index would differentiate between recent faecal and older material (i.e. dags). Statistical advice from the food safety researchers would be needed to determine and design the scoring system so as it could be underpinned by carcase hygiene measures.

The final outcome of a carcase scoring system would be to aid supply chains to bench mark their partners (producers, saleyards, transports) with respect to curfew, transport and other factors which underpin carcase hygiene. After analysis the supply chains could confidently recommend minimum curfew times appropriate to their situation.

(iv) Improving the hydration of slaughter lambs and sheep with scoping studies in cattle

It was recommended that there would be value in developing strategies to improve the capacity/willingness of lambs and sheep to consume water when it was available during lairage and in saleyards. This study would be closely linked to Industry. It was also recommended to undertake preliminary studies in cattle to examine the occurrence of dehydration (using the techniques delivered in lambs and sheep).

(v) Methods by which faecal consistency could be made firmer in sheep fed lush pasture and cattle fed lush pasture or feedlot diets

Loose faeces were highlighted by the food safety review as one of several risk factors. This is a complex area and could have several facets. There is little published data focused on understanding stool formation and consistency in sheep or cattle. Based on work in monogastric animals particular dietary components are likely to regulate stool consistency and microbial ecology in the gut. One possibly is to undertake some theoretical research to investigate factors affecting faecal consistency and microbiology. The food safety review highlighted some potential positive effects of feeding roughage and indeed some additional affects of specific roughage types. It was recommended that this work would be appropriate in very high risk groups of slaughter livestock – such as lambs consigned from certain lush pastures that might induce runny faeces.

(vi) Abattoir hygiene

While out of the scope of this review the food safety conclusions were that new research into abattoir hygiene systems should always be encouraged where appropriate given the complexity of controlling individual food (meat) borne pathogens.

Live export curfew

Overall conclusion

Stresses associated with fasting and transport of ruminant livestock result in disturbances in rumen function, leading to reductions in dry matter intake (DMI) for periods of from 3-14 days with accompanying weight losses which can range from 4-14%. The pattern of weight loss is usually curvilinear, most occurring during the first 12 hours due to gut, urine and body water losses. Better quality diets (adequate energy, protein, roughage, minerals and vitamins) are important for appetite and weight regain to occur quickly after transport to registered premises, and before embarkation of exported livestock. Health problems such as Salmonellosis in sheep and goats, influenced by inappetence, are exacerbated by fasting and transport stresses. The conclusion was that provided animals at registered premises are provided with reasonable quality diets for about 5-7 days before embarkation to allow recovery, they can tolerate feed and water deprivation associated with mustering, pre-transport curfew and transport of up to 48 hours and 32 hours in cattle and sheep/goats respectively, without long term impacts on appetite and weight stasis. Gains in recovery time for shorter fasting periods than 32-48 hours are harder to quantify. However it is suggested that the 'muster+curfew+transport' cumulative fasting time would need to be reduced to 5-12 hours if minimal interference to rumen function and live weight loss was the target.

Future research – live export curfews

Transparent recommendations on what are the determinants of a 'high quality' diet that registered premises should provide sheep and cattle 5-7 days before embarkation should be agreed upon. This could be undertaken via a workshop between researchers who have undertaken live export nutritional research and Industry practitioners. The recommendations should encompass both northern and southern scenarios.