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The live sheep export industry

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The live sheep export industry

Australia's live sheep trade to Middle Eastern countries is an important export industry. However, about 2 per cent of the sheep die, mainly during the sea voyage.

The Western Australian Department of Agriculture has conducted a major research programme to improve the health and welfare of sheep during live export. The programme has examined many aspects of the export sheep industry, and a substantial part of it has focused on why sheep die during sea transport.

Six of the articles in this issue of the *Journal of Agriculture* present the findings of that research. All articles are based on information published in the scientific literature.

The work has relied heavily on expertise in pathology (causes of death) and epidemiology (identifying the predisposing factors). Epidemiology is a relatively new area of research and uses special techniques in addition to traditional experiments.

The authors of the series of live sheep export articles in this issue are:

Richard Norris, Veterinary Epidemiologist,
Barry Richards, Senior Veterinary Pathologist, and
Tony Higgs, Veterinary Epidemiologist,
all from the Department of Agriculture.

Several officers have collaborated in professional areas of the research programme, including:

Colin McDonald, Research Officer;
Hugo Dunlop, Veterinary Epidemiologist;
Mike Hyder, Adviser;
Dr Julia Fry, Nutritional Biochemist, all from the Department of Agriculture; and
Dr Nick Costa, Nutritional Biochemist, from Murdoch University.

The programme has involved many people associated with the industry including sheep producers, feedlot managers, exporters, and ships' officers, and could not have been conducted without their wholehearted co-operation.

The research was funded by the Australian Meat and Livestock Research and Development Corporation and the Commonwealth Department of Primary Industries and Energy.

A list of references and publications on areas of research related to deaths of live sheep exported by sea is on page 148.

The main Middle East markets for Australia's live sheep. Half the total number of sheep exported are loaded at Fremantle.
Importance of live sheep exports

The sea transport of live sheep from Australia for slaughter at overseas destinations is a large industry. Until the trade was disrupted in 1989 about seven million sheep were exported each year, mainly to Middle Eastern countries.

The industry returned almost A$250 million in export income to the Australian economy each year, and provided considerable employment in areas such as livestock production, transport, feed milling and supplies to ships.

The markets

The main Middle East markets for our live sheep from 1980 to 1990 were: Saudi Arabia, Kuwait, the United Arab Emirates and Qatar. During this period almost half the number of sheep exported annually were sent to Saudi Arabia.

Other countries which have been irregular buyers of Australian sheep include Algeria, Libya and Iran. In South-East Asia, Singapore imports about 40,000 sheep each year.

Live sheep are imported for slaughter in the Middle East, as distinct from sheep carcasses, because of traditions and religious beliefs of people of the region. The custom among most Middle Eastern people is to buy sheep live for halal slaughter and consumption on the same day.

Overview of the export process

The purchase, assembly and export of a consignment of sheep is a substantial logistical exercise. The sheep are bought on-farm and trucked by road to an export feedlot. After several days in the feedlot, where the sheep are given pelleted feed, they are trucked to a port and loaded aboard ship for the sea voyage.

Close co-operation is needed between the export company, the buyers, truck-drivers, feedlot managers, personnel at the wharf and aboard ship, and importers in the Middle East.

Feedlots

Sheep are trucked to the feedlot about three to 14 days after purchase on the farm. Receivals at the feedlot usually span a period of two to four days.

The sheep are counted during unloading from the truck and those with injury, overt ill-health or that are 'not-to-specification' (wrong sex or those in poor condition) are rejected. Rejected animals are either destroyed or sold for slaughter.

The sheep usually spend five to 10 days at the feedlot. They may be vaccinated as specified by the importing country, shorn, drafted and the rams dehorned during this period.

Most feedlots consist of many small paddocks and are located close to the major loading ports at Fremantle in Western Australia, Portland in Victoria and Adelaide in South Australia.

Sheep are usually fed hay initially and this is gradually replaced over about five days with a pelleted diet. At one feedlot near Fremantle, the sheep are housed entirely in sheds and are fed a diet consisting solely of pellets from the day of arrival.

The feedlot serves two important functions. It is a depot where the consignment is assembled and where appropriate husbandry procedures are completed.

Also, a period of time in the feedlot provides an opportunity to accustom the sheep to the pelleted diet they are to receive aboard ship. The feed pellets are made mostly from roughage and cereal grain; in Western Australia lupin seed is often added.

Loading

The sheep are trucked by road from the feedlot to the wharf and then inspected by quarantine officers of the State Department of Agriculture. Sheep with overt ill-health or 'not-to-specification' are again rejected.

Almost half the number of sheep exported from Australia are loaded at Fremantle. The remainder are shipped mostly from Portland and Adelaide, with occasional shipments from other ports.

Loading the ship is usually completed in one to four days, depending on the capacity of the vessel. The sheep are housed aboard ship in...
pens and on most decks there are two tiers (levels) of pens. The vessels vary in design: some ships have only open-sided decks (open deck type), others have only enclosed decks, while most have both deck types.

Many shipments are unloaded at a single port in the Middle East, but large vessels carrying more than 50,000 sheep are usually unloaded at two or more ports. After unloading, the sheep are trucked to nearby feedlots where they are held until sold for slaughter, mostly within three weeks.

Control of the industry

The live sheep export industry is controlled by various bodies. Each export company is responsible for the health and welfare of sheep under its control and is represented on the Australian Livestock Exporters Association (ALEA).

The ALEA meets regularly to consider relevant issues and interacts with other organizations associated with the industry. Members of the ALEA are expected to comply with national standards that have been established for several areas of the industry, including those for road transport of livestock, feedlots, feed quality and sea transport.

The Australian Meat and Livestock Corporation (AMLC), the Federal Department of Primary Industries and Energy (DPIE) and the Federal Department of Transport and Communications (DOTC) regulate the industry. The AMLC licenses exporters and authorises the sailing of each shipment of sheep; DPIE certifies that the health requirements of importing countries have been met; and DOTC regulates ship design and the loading of cargo.

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After each voyage, the ship's Captain must submit a voyage mortality report (Master’s report), that contains basic epidemiological information, to the Federal Department of Transport and Communications.

Health and welfare of export sheep

There is much concern about the health and welfare of export sheep.

In 1985 the Senate Select Committee on Animal Welfare, following an enquiry into the live sheep trade, made many recommendations for improved husbandry and for research. Of particular concern was death rates of sheep at sea which were thought to be about 2 per cent a year, having fallen from more than 4 per cent in the mid 1970s.

The Committee was critical of the trade on animal welfare grounds and considered that “it is not in the interests of the animal to be transported to the Middle East for slaughter”.

However, the Committee acknowledged that animal welfare aspects of the trade could not be divorced from economic and other factors. Consequently, the Committee agreed that the trade would continue “for some years” providing significant improvements were made to animal welfare.

In recent years there has been a substantial research effort by officers of the Western Australian Department of Agriculture to improve the health and welfare of sheep during all phases of the export process. Areas of research included causes of death and the predisposing factors, feedlot management and aspects of feed pellet formulation.
Deaths of sheep during the phases of export

Experience in the live sheep export trade and concern about the welfare of the sheep led to many improvements in management in the 1970s. As a result, death rates of sheep on ships declined substantially.

Improved management included the introduction of specialised ships (mostly converted oil tankers) with pens designed specifically for carrying sheep, and better diet.

There was a change in shipboard diet from hay, fed on the pen floor, to pelleted feed given in troughs that were raised to minimise faecal contamination. The feed was pelleted to improve handling and storage, and the formulation was modified progressively to minimise crumbling of the pellet and sheep acidosis. In addition, the pelleted feed was first given to the sheep in the feedlot before the voyage.

Ventilation in sheep-pens aboard ship improved because of the better design of housing, including the installation of fans, and elimination of hay which frequently impeded air flow in older vessels. Hay fed on the pen floor also contributed to faecal-oral cycling of gastrointestinal microbes that cause disease in the sheep, and generated unwanted heat aboard ship when decomposing.

There were also substantial improvements in feedlot design and management arising partly from research conducted in the early 1980s by Department of Agriculture officers C.L. McDonald, R.T. Norris, J.B. Rowe and others.

Factors contributing to deaths
Sheep that arrive at a feedlot before live export by sea must recover from the effects of truck-age and condition feed management duration —

Wheelbarrows are used to fill the feed troughs with pelleted feed aboard ship.

Figure 1. Many factors may contribute to sheep deaths during the phases of export.

Sheep eating the feed aboard ship.
ing, adapt to a new physical and social environment, and adapt topelleted feed.

At the start of the Department of Agriculture's mortality study in 1985, there was limited information on sheep death rates during the export process. There was some confusion about the causes of the deaths, arising from conflicting reports that were seldom published in the scientific literature.

Consequently, many factors were presumed to contribute to sheep deaths in the trade, but there was little objective information. However, the industry was generally of the view that most of the sheep that died during the sea voyage had not eaten the pelleted feed.

Sheep may be prone to death during sea transport from Australia because of many factors. These include the nutritional and management history of the sheep, trucking from farm of origin to feedlot, lot-feeding and shipping (Figure 1).

**Death rates**

The industry has unique problems mainly caused by the need to transport sheep long distances by sea while maintaining their liveweight. It was considered that the first steps in identifying the important predisposing factors, and thereby reducing mortality, were to define the death rates and to establish the cause(s) of death.

Various studies, including research voyages and examination of industry records, indicate that about 3 per cent of sheep that leave the farm for export are rejected or die before discharge in the Middle East (Figures 2 and 3).

Few sheep die during trucking to the feedlot or during lot-feeding. A substantial number of sheep are rejected as unsuitable for export, for various reasons, both during lot-feeding and at wharf-side inspection. However, the major source of loss is deaths aboard ship.

Death rate of sheep aboard ship has fluctuated about the figure of 2 per cent since 1980. Shipboard death rates (as a percentage of sheep loaded) of all sheep exported from Western Australia from 1985 to 1989 are shown in Figure 4.

Most of the sheep that die at sea do so before arrival at the first port of unloading; there are few deaths at loading. However, substantial numbers of sheep die during the unloading phase of the voyage. Many ships unload at more than one port and deaths after arrival at the first port are considered as discharge deaths.
Causes of sheep death during sea transport

The main causes of sheep deaths aboard ship are failure to eat (inanition) and salmonellosis. Together, these two causes account for about three-quarters of the two per cent total deaths aboard ship (Figure 1).

Studies aboard ship

The major causes of sheep deaths during sea transport were determined after many hundreds of shipboard post-mortems on voyages to the Middle East. Veterinarians conducted daily examinations on dead sheep and collected specimens for laboratory follow-up. Specimens were allowed back into Australia with strict quarantine precautions and processed at the Department of Agriculture's Animal Health Laboratories, South Perth.

There were numerous problems associated with storage of specimens and often several weeks elapsed between collection and receipt in the laboratory. However, methods were devised to permit satisfactory bacteriological, histopathological, serological, biochemical and electron-microscopic examinations.

Sheep identified to farm of origin at arrival in the feedlot were monitored throughout export. Dead sheep were examined in great detail to determine the cause of death.

Many diseases were identified. For simplicity, sheep deaths were grouped into four categories; those that died of:

- failure to eat (inanition),
- gastroenteritis caused by salmonellosis,
- traumatic injuries, and
- miscellaneous diseases, of farm origin.

Inanition (failure to eat)

About half of all sheep that die during sea transport to the Middle East do so because they fail to eat from the moment they leave the farm. With annual shipboard death rates of about 2 per cent, this means that up to 75,000 sheep per year die because they persistently refuse to eat.

Live sheep export research conducted in Western Australia, Victoria and South Australia has identified failure to eat as the major cause of death in the live sheep export industry. Several terms have been used to describe the syndrome including 'shy-feeding syndrome', 'starvation', 'inanition', 'anorexia', 'failure to eat syndrome', 'voluntary feed refusal' and 'persistent inappetance'.

These sheep don't eat the food they are given. The evidence suggests there is an abnormality of appetite control that is not related to social factors, quantity of feed or its availability.

Sheep that fail to eat may die for several reasons. Many succumb to salmonellosis because the environment in the gastro-intestinal system changes to favour growth of the organism. Some develop low concentrations of blood magnesium and/or calcium which leads to tetany and death, and some succumb to repeated trauma. However, a recent discovery indicates that time of the year may also be important.

Body fat reserves are rarely depleted in sheep that die from persistent inappetance. On the
contrary, they usually have ample body fat. Fatty change in the liver is never excessive, as in ewes with pregnancy toxaemia or in cattle with fatty liver syndrome. However, there is often some degree of liver damage which is thought to have a detrimental effect on appetite.

The rumino-reticulum is usually shrunken; in severe cases the organ is reduced to the size of two tennis balls, in contrast to the normal size exceeding five litres. Microscopic examination shows there is extreme shrinking of the lining tissues indicating a lack of absorptive capacity.

About one third of sheep that die because they fail to eat have microscopically detectable degeneration of certain skeletal muscles. This lesion appears up to a few days before death and may be one of the reasons some sheep succumb to trauma after prolonged inappetance.

Biochemical studies have shown that sheep coming from green pastures in the second half of the year have a reduced capacity to use stored body fat as an emergency source of energy. Consequently, these sheep have to resort to other, presumably less efficient, methods of providing energy. This results in higher death rates.

Sheep less than three years old have much lower death rates than older sheep. Young sheep have stronger appetites because they are eating for growth as well as maintenance, and seasonal cycles don’t affect them as much as older sheep.

An important finding was that sheep from some farms had high death rates and sheep from other farms had low death rates and often no deaths at all. This suggests that the on-farm environment plays a crucial role in the development of the syndrome.

Salmonellosis

Infection with salmonella bacteria can cause serious gastroenteritis which frequently leads to death. The biggest single predisposing factor for salmonellosis is inadequate feed intake. Sheep that are ‘shy feeders’ have an increased risk of death from salmonellosis. Shipboard studies have shown that about six of every seven sheep that die of salmonellosis are shy feeders.

Repeated investigations have confirmed that less than 2 per cent of sheep excrete salmonella in their faeces on arrival at the feedlot. However, after several days in the feedlot about 4 per cent of sheep excrete salmonella bacteria, and after eight or nine days on board ship

Salmonellosis in sheep can cause deaths; note the reddening of the intestines.

The inside of a sheep showing abundant reserves of abdominal fat. Sheep that died aboard ship had ample body fat.

The rumen of sheep that refuse to eat aboard ship may shrink to the size of two tennis balls; the cup in the photo has a diameter of about 8.3 cm.
about 12 per cent are excreting the organisms. Excretion rates are generally much higher in fasting sheep than in those feeding regularly.

Epidemiological studies have shown that although the feedlot and shipboard environments become increasingly contaminated with salmonella bacteria, it is primarily those sheep that are not eating or are 'stressed' for some other reason that succumb to infection. Healthy sheep, with strong appetites, are usually able to withstand the challenge from salmonella.

The serotypes of salmonella isolated from diseased sheep were similar to those that occasionally cause deaths on farms in Western Australia. The most commonly isolated serotypes were *Salmonella typhimurium*, *S. bovis-morbificans* and *S. Havana*.

A prototype salmonella vaccine against these three serotypes was tested under industry conditions and showed promising results. Whether or not it is eventually recommended, after further development, will depend on the results of efforts to curb the persistent inappetance syndrome.

Elimination of shy feeding should largely solve the salmonellosis problem.

**Trauma**

About 12 per cent of the 2 per cent of sheep that die during shipping do so as a direct result of injuries sustained during loading of the ship and in the first few days of the voyage. This cause of death has declined since 1985 as a result of careful handling of sheep at all stages and the use of non-slip flooring on many vessels.

**Miscellaneous diseases**

A great many diseases were recorded during shipboard studies over the past six years. Collectively, they contribute in a minor way to the overall death rate.

Most were diseases commonly seen on Western Australian farms. Affected animals had entered the export process without showing sign of ill-health but later had succumbed. Diseases encountered included degenerative myopathy (muscle disease), lupinosis, foot abscess, urinary calculi (kidney stones), pneumonia and dehydration. Significantly, there was virtually no acidosis (over-eating or grain overload) in sheep aboard ship.

**Heat stress**

Excessive temperature and humidity does occasionally cause deaths on board ship.

Prolonged discharge at Gulf ports during the northern hemisphere summer is sometimes associated with high mortality rates because natural ventilation is non-existent while the ship is stationary. This constitutes a serious animal welfare issue, but it is usually a small proportion of total deaths.

**Mortality profiles**

Daily mortalities during shipping form distinct patterns (Figure 2). Of the major profiles, Type I is associated with an increasing proportion of inanition deaths, Type II is caused by a peak of salmonellosis deaths at about seven days, and Type III involves a mixture of all causes. The mortality profiles are a reflection of both the conditions in the pre-export feedlot and the factors (as yet unknown) that operate on the farm of origin.

We concluded that the major cause of death during shipping is persistent, voluntary, inappetance. Sheep that do not eat are more prone to salmonellosis. Together these two causes account for about three-quarters of all sheep deaths.

![Figure 2. Patterns of daily sheep death rates aboard ship.](image-url)
The main predisposing causes of sheep deaths at sea include: age of the sheep, failure to eat the pelleted diet, farm group, fatness, season, temperature and humidity, duration from the farm gate to the end of the voyage, and ship design.

These were some of the many possible predisposing factors that the Department of Agriculture has investigated during a large research programme since 1985. The programme has involved analysis of industry records, as well as having veterinarians accompany shipments of sheep to the Middle East and Singapore.

Age of sheep

In 1987, several shipments of hoggets (less than four permanent incisor teeth) were sent to Algeria. Death rates were remarkably low throughout these long voyages compared with death rates of adult wethers sent to the Middle East. The pattern of low mortality in hoggets, seen in Figure 1, was repeated on other voyages of the same ship and on other ships to Algeria.

In 1989, the industry began collecting more detail on deaths aboard ships as part of a new national recording system. The system, coordinated in Western Australia, showed that the overall death rate in hoggets was about 30 per cent of the rate of adult wethers (Figure 2, page 140).

Ewe and wether lambs also had low death rates compared with adult wethers, but mortality in ram lambs was relatively high. The reasons why mortality is high in adult wethers appear to be related to the hormonal control of appetite, and seasonal factors.

Failure to eat

Failure to eat pelleted feed has long been a suspected predisposing cause of shipboard mortality, but there was little objective evidence at the start of the project.

Large numbers of sheep were selected for inclusion in Department of Agriculture studies on receipt at commercial feedlots. About 10,000 sheep per voyage were given ear-tags to identify the farm of origin.

Figure 1. Daily death rates in adult wethers and hogget wethers in consecutive voyages of one ship.
Changing the colour of the dye used on bars at an outdoor feedlot.

Marker bars, covered with dye and attached to feed troughs, were used to identify sheep that ate pelleted feed during lot-feeding. Non-feeders, sheep that failed to eat pelleted feed, were given an extra ear-tag for easy identification aboard ship. Sheep within these groups that died during the voyage were post-mortemmed to determine the cause of death.

Sheep that did not eat pelleted feed in the feedlot were about six times as likely to die aboard ship as were normal feeders (Table 1). When the causes of death were considered, feedlot non-feeders were about seven times as likely to die from inanition and about six times as likely to die from salmonellosis.

These findings indicated that failure to eat pelleted feed in the feedlot is a predisposing cause of death aboard ship. Surprisingly, however, most feedlot non-feeders begin eating soon after being loaded aboard ship.

Farm group

Livestock husbandry differs between farms, and therefore many aspects of animal health and production also differ between farm groups of sheep. In addition, earlier studies had shown differences between farm groups in the number of sheep that ate pelleted feed under simulated export conditions.

As described above, truckloads of sheep that arrived at commercial feedlots for live export were identified to the farm of origin.

The objective was to examine for differences in shipboard mortality between farm groups (or lines) of sheep. An additional objective was to collect information on the nutritional and management history of each line and to assess whether any of the factors contributed to mortality. Sheep producers and truck drivers readily provided the information sought.

As expected, there were substantial differences between lines, with death rates aboard ship ranging from zero to 20 per cent on the same voyage. However, it was a surprise to discover that more than half the deaths in all voyages combined were in only 25 (13 per cent) of the 189 lines of sheep (Table 2).

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<tr>
<th>Table 1. Death rate and risk of death aboard ship in sheep that ate or did not eat pellets during lot-feeding</th>
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<td>Voyage</td>
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<td>ND: not done</td>
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<tr>
<th>Table 2. Percentage of farm groups (lines) and sheep deaths in various categories of mortality</th>
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<td>Mortality level within individual lines</td>
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<tr>
<td>Observation</td>
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<td>Proportion of lines (%)</td>
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<td>Sheep deaths (%)</td>
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Therefore, if high mortality lines could be identified before purchase and managed differently, or not bought for export, overall death rate would be reduced substantially.

Many factors in the history of the sheep were examined in the search for explanations. However, the results were not encouraging.

After much investigation, including farm visits, it is now apparent that some factors have little or no effect on mortality. These include: region of origin, previous experience of mixing with other sheep (dealer's sheep or home-bred sheep), experience of trucking and of supplementary feeding, distance trucked from farm to feedlot, and time off feed on arrival at the feedlot.

There is no evidence of repeatability in death rate between batches of sheep from the same farm. This is because of the variation with time in the many factors that may predispose to sheep deaths aboard ship. Consequently, each voyage is unique for the possible combination of these factors.

**Fatness**

An unexpected finding of earlier post-mortem studies was that sheep which died of inanition had ample reserves of body fat. This suggested that fatness may have been a predisposing cause of death but the finding was not conclusive.

Therefore, sheep were scored for body condition on receipt at the feedlot before three voyages accompanied by veterinarians. It was found that fatness was correlated with mortality at the farm line level in two of the voyages.

In addition, individual fat sheep (condition score 3 or more) were identified at the feedlot before one voyage. Fat sheep had twice the risk of death from failure to eat as lean sheep.

These results confirmed the earlier observation that fatness is a predisposing cause of death aboard ship.

**Season of the year**

Industry opinion was that shipboard death rates of sheep were highest about July and August, coinciding with times of highest temperature and relative humidity in the Middle East.

Consequently, mortality from the end of loading to arrival at the first port of destination was calculated for each voyage from 1985 to 1989. The average death rate over five years was plotted according to the month that loading began (Figure 3).

Although the results in Figure 3 appear to support industry opinion, death rates were not statistically significantly higher in July to September than in October to December. However, death rates were statistically significantly higher in the second half of the year than in the first half. The risk of death aboard ship in the second half of the year was twice that of the first half in all years except 1985.

In south-west Western Australia sheep are fatter in the second half of the year than in the first half. Therefore, this finding is consistent with the previous observation that fat sheep had a higher risk of death than lean sheep.

**Temperature and relative humidity**

Even though industry opinion was not supported in relation to death rates overall, high death rates of sheep have occasionally been associated with extremely hot and humid conditions.

In most cases, the temperature exceeded 35°C, the humidity was 85 per cent or higher and there was little or no air movement through the pens. However, results from 328 voyages involving 14 million sheep over five years indicate that these episodes were uncommon and that the contribution to mortality over the full year was relatively small.

![Figure 3. Average death rate of sheep aboard ship according to the month that loading began.](image-url)
In some Middle Eastern ports sheep are unloaded from the ship into small trucks for transport elsewhere.

**Duration of export process**

The total number of sheep deaths increases with increasing number of days since leaving the farm, even though the number of deaths on any given day may vary considerably.

Therefore, it is important to minimise the number of days that sheep spend in the export system between leaving the farm and unloading at the destination port.

Options to minimise the time that sheep spend in the system include reducing the duration of lot-feeding and increasing the rate of unloading once the ship arrives at the first port of destination.

Our observations support the view that the duration of lot-feeding should be minimised. An important finding is that nearly all sheep which do not eat pelleted feed in the feedlot readily begin eating aboard ship. About five days appears to be the minimum needed to assemble a large consignment of sheep and complete appropriate husbandry procedures. Prolonged lot-feeding is therefore unnecessary and increases the risk of death from inclement weather and salmonellosis.

Facilities and management differ widely at ports in the Middle East. At some ports it is possible to unload directly into feedlots or holding pens at the wharf. Unloading is rapid and may exceed 3,000 sheep per hour, without injury to the sheep. At other ports, the sheep are unloaded into trucks of capacity from 500 to only 60 sheep. Consequently, unloading may be less than 800 per hour.

Slow unloading places an extra burden on the crew who also must continue feeding and watering the remaining sheep. It also increases the risk of sheep dying from heat stroke in extremely hot weather.

In addition, ships of large capacity frequently call at two or more ports. This results in some sheep spending unnecessary extra days aboard ship.

**Ship design**

About 16 ships carry sheep to the Middle East from Australia. Mortality of sheep was compared between ships to establish whether any ship offered an advantage to the sheep.

Consistently low mortality was observed on one vessel. This ship carried relatively young sheep on short voyages and its design provided the animals with plenty of air movement.

Most vessels gave 'medium' levels of mortality. However, two ships often recorded high mortality; one has since been scrapped and the other is under investigation.

**Ship decks**

Decks aboard ship may be open-sided, relying mainly on natural ventilation, or enclosed relying entirely on fans for ventilation. In addition, each deck has two tiers or levels of pens. Mortality was compared between deck types and tiers to see if either contributed to sheep deaths.

Adult wethers in enclosed decks had an 18 per cent greater risk of death than sheep in open decks. Although most ships have both open and enclosed decks, such vessels are relatively small. Only about 19 per cent of sheep exported in 1989 were carried in enclosed decks.
Consequently, the extra deaths associated with enclosed decks amounted to about 1,300 sheep. Bigger ships have mostly open decks.

Death rates were frequently higher in upper tiers than in lower tiers, although the finding was not consistent. The risk of death in upper tiers was 17 per cent greater than that in lower tiers and the extra deaths amounted to about 2,500 sheep.

Although enclosed decks and upper tiers may each predispose to mortality, the effect is not consistent and the risk is small compared with other factors. Therefore, the research has focused on the main factors such as age, season of the year, fatness and appetite in export sheep.

**Feed quality and quantity**

The nutritional value of the pelleted diet was assessed as a possible predisposing cause of death aboard ship.

One hundred feed samples collected in 1985 and 1986 were analysed for quality. The samples largely conformed to national standards for pellets in the live sheep export industry. These findings, plus the results of on-going monitoring of pellet quality, indicate that the nutritional value of the diet is not a predisposing cause of death aboard ship.

Adult wethers are fed to maintain liveweight during the sea voyage. Theoretically, they require pellets fed at a daily rate of 2 per cent of liveweight, about 1.1 kg each per day, for maintenance. However, incidental observations from several studies suggested that this amount was inadequate.

Experiments were then conducted at Katanning by Department of Agriculture officers C.L. McDonald, B.E. Warren and others to establish the amount of feed necessary for maintenance of liveweight. Their findings indicated that 50 to 65 kg wethers needed some 20 to 30 per cent more feed than theoretical levels suggest.

Adult wethers are fed at least 1.1 kg of pellets daily and, on average, lose about 2 kg of liveweight during the voyage. Although this amount of loss is consistent with 'maintenance', a small increase in quantity fed would more closely achieve the objective.

The reasons why wethers need more feed to maintain liveweight, than theoretical estimates, are under investigation.
Minimising sheep deaths aboard ship

Previous studies showed that sheep which failed to eat pelleted feed in the feedlot had a higher risk of death aboard ship than those that ate the feed.

Options available for the management of sheep before loading onto ships include housing the sheep in sheds, and separating non-feeders from other sheep at the end of lot-feeding and giving them extra feed.

Feedlots

Several problems have been associated with sheep held in feedlots consisting of small paddocks.

These problems include environmental concerns such as denuding of feedlot vegetation resulting in soil erosion and dust, and increased levels of phosphate and nitrogen from manure entering groundwater supplies.

In addition, sheep held outdoors are often subjected to cold, wet conditions in winter that may predispose to diseases such as salmonellosis.

Lot-feeding in sheds offers considerable advantages in sheep husbandry over lot-feeding in paddocks. At two Western Australian feedlots, the sheep are housed exclusively in sheds. It was decided to compare the two methods of lot-feeding in the preparation of sheep for live export.

Studies were conducted in autumn and in spring. Before each study, truckloads (lines) of sheep were eartagged and half of each line was lot-fed outdoors with the remainder lot-fed indoors. The indoor and outdoor groups, about 4,000 sheep in each, were fed pellets *ad libitum* without hay. Bars covered with dye were attached to feed troughs to identify sheep that ate.

The number of sheep that did not eat pelleted feed was recorded at intervals of about 48 hours during lot-feeding. On the last day in the feedlot, indoor and outdoor groups were mixed and loaded onto the same deck aboard ship.

More of the outdoor lot-fed sheep ate pelleted feed than did those fed indoors on most occasions during lot-feeding (Table 1). There were also more non-feeders indoors in the autumn study. However, there was no statistically significant difference in shipboard death rate from all causes or from inanition or salmonellosis in either the autumn or spring voyages.

These findings suggested that the extra non-feeders from the indoor lot-fed group started eating pelleted feed aboard ship. Results indicated that lot-feeding in sheds did not adversely affect death rates aboard ship.

Management of inappetant sheep

Simulated voyage

Earlier studies had shown that sheep that did not eat pelleted feed during lot-feeding (non-feeders) had about a six-fold greater risk of dying during the sea voyage. It was suggested that providing extra access to feed troughs or extra feed may be beneficial to non-feeders during shipping.

This study was done by C.L. McDonald in collaboration with the authors and others. At the end of commercial lot-feeding, 324 non-feeders were trucked to Katanning and given one of three treatments during a simulated voyage. The treatments were: standard management (3 cm of trough length, 1,000 g of pellets per day); extra trough length (8 cm per sheep); extra feed (*ad libitum*). The simulated voyage lasted 22 days.
Most non-feeders (85 per cent to 93 per cent in each treatment) ate pelleted feed during the first three days of 'shipping'. There was no advantage in the number of sheep that ate or in liveweight change by feeding *ad libitum* or having longer feed troughs.

An unexpected finding was that a small number of sheep ate little or nothing in each treatment group, and that giving them feed *ad libitum* had no effect. These sheep did not eat pelleted feed despite plentiful availability, and were termed 'persistent non-feeders'.

It appears that 'persistent non-feeders' lose appetite soon after leaving the farm and that it is these sheep that are most likely to die of inanition or salmonellosis aboard ship.

**Voyage to the Middle East**

Because of limited resources, the study described above was not able to examine for effects on mortality. Veterinarians therefore travelled with a shipment to the Middle East to assess whether separation of non-feeders from feeders, at the end of lot-feeding, would lower death rates.

About 12,000 sheep were divided equally into treatment and control groups on receipt at a commercial feedlot. Non-feeders were identified at the end of lot-feeding and given an extra ear tag. In the treatment group, non-feeders were loaded separately aboard ship from the feeders. However, non-feeders were mixed with feeders in the control group and loaded onto the same deck as sheep in the treatment group.

There was no significant difference in shipboard mortality between treatment (1.1 per cent died) and control groups (0.9 per cent) or between non-feeders in treatment (7.5 per cent died) and control groups (10.7 per cent). As observed previously, more than 85 per cent of non-feeders began eating pelleted feed in the first five days of the voyage.

**Therapeutic treatments for export sheep**

Several factors that could predispose sheep to inappetance and death aboard ship had not been fully studied. These included a low level of internal parasites and deficiencies of vitamins and minerals such as *B<sub>12</sub>, E* and magnesium.

To save time, the treatments were combined into a 'cocktail' that was applied to half of each line (farm group) of sheep before a voyage. The untreated half of each line constituted the control group.

Ivermectin (a worm drench) and vitamin *B<sub>12</sub>* were given to all sheep in the treatment group on receipt at the feedlot. Non-feeders were separated from feeders at the end of lot-feeding and vitamins *B<sub>12</sub>, E* and magnesium were given to non-feeders in the treatment group only.

Non-feeders from the treatment and control groups were then mixed and loaded separately from feeders aboard the ship, to increase chances of detecting freshly dead sheep. Feeders in the treatment and control groups were also mixed and loaded onto the same deck.

Remarkably, there were 21 per cent fewer non-feeders in the treatment group at the end of lot-feeding and 43 per cent fewer deaths during the voyage.

These findings indicate an effect of either ivermectin or vitamin *B<sub>12</sub>* or both given at receipt. However, faecal worm egg counts were low in sheep at receipt suggesting that internal parasitism was negligible. It is therefore considered that giving vitamin *B<sub>12</sub>* was the likely reason for the result.

However, it is also possible that one or more of the treatments given to non-feeders at the end of lot-feeding contributed to the result. There were fewer deaths and less liveweight loss in treated non-feeders than in the control non-feeders.

Therefore, additional work is needed to identify the successful treatment(s) and to develop cost-effective strategies for adoption by the industry.

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<th>Feedlot and ship</th>
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<th>Spring voyage</th>
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Table 1. Effect of lot-feeding in sheds or paddocks on per cent of sheep that eat in the feedlot and on survival aboard ship
Future directions to reduce sheep deaths

The large research programme in Western Australia into live sheep exports has defined sheep death rates during the export process and established the causes of death (see box on page 147).

Examination of many possible predisposing factors, at all stages of the export process, has identified the main ones and suggested the direction of future research.

Biological explanation

The results of Western Australian research have made it possible to explain why shipboard death rates of sheep are higher in the second half of the year than in the first half, and why some farm groups of sheep have high death rates during shipping.

The answers are related to the biological clock, and its annual cycle, that is present in all sheep.

The driving force behind the annual cycle is day-length, or photoperiod. Acting through the brain, photoperiod governs a variety of normal body functions including appetite, metabolic rate, wool growth and reproduction.

Both appetite and metabolic rate are diminished in winter and enhanced in summer. Together with pasture availability, which is strongly seasonal in south-west Western Australia, the effects of photoperiod produce two distinct phases of liveweight change in mature sheep: liveweight loss from December to May, and liveweight gain from July to November (Figure 1, page 148).

Research elsewhere has shown that the carcass component in mature sheep most affected by this fluctuation is body fat. Mature Merino wethers in south-western Australia are therefore accumulating body fat as they graze green pasture from July until November, and losing body fat on dry pastures from December to May.

Evidence from blood samples

Evidence that these seasonal cycles might be involved in death rates during shipping came from examination of biochemical products in blood taken from sheep during export to the Middle East at two critical times of the year: May and August.

In the two groups of sheep studied, the level of fatness (condition score) was the same, but May sheep were at the end of their weight loss phase and August sheep were at the start of their weight gain phase. Both groups of sheep were prepared in the same feedlot, fed the same ration, shipped on identical ships and the comparison was made on the first 12 days of each voyage.

However, the death rate during shipping was four times higher in August (3.27 per cent) than in May (0.83 per cent). The causes of death were similar in the two groups, with 65 per cent of deaths caused by inanition.

Blood samples, taken from sheep at various stages of lot-feeding and shipping, were analysed for several products to examine protein and energy metabolism in each group of sheep. Almost 7,000 tests were conducted on these blood samples and the results were a revelation.

Non-feeding sheep in May were able to successfully draw on their body fat reserves to supply energy, whereas inappetant sheep in August were unable to mobilise fat for more than a few days. Given that the number of potential non-feeders was the same at both
times of the year, it was then a question of survival. Non-feeders had a much higher risk of death aboard ship in August than in May.

We postulated that sheep coming from dry pastures, during their period of liveweight loss, and in a negative energy balance, were metabolically adjusted, or 'tuned' to using fat reserves for energy so that any sheep refusing to eat had a better chance of survival.

Alternatively, sheep coming from green pastures and in a positive energy balance, had a metabolism geared to fat deposition; those that refused to eat were not able to adjust to the sudden requirement for extra energy and their survival was at risk.

The hypothesis can be extended to explain why young sheep have much lower death rates during export than mature sheep.

Put simply, immature sheep have such a tremendous growth requirement that their strong appetite overrides other considerations. Consequently, there are likely to be fewer non-feeders amongst immature sheep.

The strong appetite drive in young sheep, a common observation during export, means that the seasonal cycles so crucial to survival in mature sheep have much less influence in immature sheep.

What remains elusive is the full explanation for high shipboard death rates in some farm groups of sheep, although some of the reasons are known.

Our current understanding is that the seasonal effect on body fat may be more pronounced in some farm groups of sheep than in others. One possibility is that sheep gaining weight rapidly on good green pastures are less capable of making the transition to dry feed than sheep gaining weight slowly on green pasture.

The fact that many lines of sheep exported in the second half of the year have no deaths at all is evidence that a solution is possible. The challenge is to find it.

Future directions for research

The general thrust of our research has been to identify the main causes of sheep deaths aboard ships and the predisposing factors. This will ensure that future research dollars are spent wisely, in areas with the greatest potential for economic return and improved animal welfare.

The area that contributes most to wastage in the industry is shipboard mortality. The main variation in shipboard death rate is associated with the farm group of sheep. Consequently, future research should be directed towards minimising this variation.

The results so far suggest that age, season of the year and fatness are all associated with farm-group variation in mortality. Young sheep in store condition, shipped during the first half of the year, have the lowest risk of death.
However, our overseas customers want wethers of 50 to 65 kg liveweight throughout the year. Consequently, sheep in the high risk category (forward store, mature wethers, in the second half of the year) will continue to be exported. Future research should be directed at minimising death rates in this high risk group.

The encouraging findings include improved appetite following treatments given in the feedlot, and the discovery that metabolic maladjustments are largely responsible for the high death rates of sheep aboard ship in the second half of the year. There is reason to be optimistic, given that all sheep survive in some lines in the high risk category.

If research expenditure is directed at these targets the probability of success is enhanced.

Further Reading


