TRANSPORT OF SHEEP AND CATTLE

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INTRODUCTION

In this review we will consider the effects of land transportation on sheep and cattle (castrated males and females) and on the yield and quality of their meats. We suggest stratagems to reduce the, almost inevitable, losses in yield and quality which occur when cattle and sheep are transported to slaughter and to discuss some of the problems of researching in this area.

All animals that do not die of natural causes are transported to slaughter. The effects of transportation on the animal cannot, usually be determined in isolation from loading and unloading. Similarly, effects on meat yield and quality cannot be evaluated in isolation from lairage, preslaughter handling, slaughter and carcass processing procedures. The transportation phase is complex and to ensure that the delicate product (the live animal) is conveyed from farm to slaughter with a minimum of stress and maximum yield and quality requires the informed cooperation of all involved.

LOSS OF PRODUCT MASS

The liveweight of an animal consists of the weight of body tissues plus those of the contents of the alimentary tract (gut fill) and bladder. Losses from any of these components, including tissue moisture, will reduce liveweight. Loss of carcass and organ weights can result from dehydration and catabolism. Trimming of bruised tissue reduces carcass weight and condemnations of organs, or carcasses, result in a loss of product mass.

The extent of liveweight losses in cattle deprived of feed and water, with, or without, transport, taken from the results of 26 publications, are shown in Fig 1; the rate of liveweight loss decreases with time off feed and water.

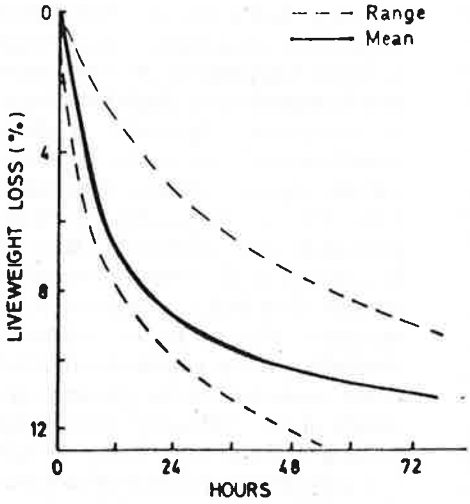

FIG. 1 LIVEWEIGHT LOSS, AS A PERCENTAGE OF INITIAL LIVEWEIGHT, OF CATTLE DEPRIVED OF FEED AND WATER (WITH OR WITHOUT TRANSPORTATION)

The rates of liveweight decreases reported for lambs and sheep during preslaughter fasting vary from 2.2 to 8.2% per day (George et al. 1966; Kirton et al. 1967, 1968; Warris et al. 1987).

Shorthose (1965) estimated, from data of Mulhearn (unpublished) and Salerno (1949), that carcass weight loss of cattle deprived of feed and water and transported to slaughter was, approximately, 0.75% (of "on-farm" carcass weight) per day if carcass weight loss was deemed to start after the first day of feed and water deprivation. In recent, Australian, studies (Wythes et al. 1981; Holmes et al. 1982) the extent of carcass weight loss of steers and cows marketed over a 3 to 11 day period varied from 0.3 -0.5% per day.

Kirton and Paterson (1973) recorded much greater losses (5%) in the hot carcass weight of young calves (liveweight < 45 kg, carcass weight 〉 10 kg) in 24 h of preslaughter starvation. The mean carcass weight loss of lambs and sheep over 0.5 to 4 days off feed and water (Shier 1939; Callaghan and Thompson 1940; C.C.C.A.B. 1943; Kirton et al. 1967, 1968; O'Halloran 1986; Warris et al. 1987) was 1.5% per day with losses starting about 12 h from the start of feed and water deprivation. Kirton et al. (1967) found that a 3 day, rather than a 1 day, fast before slaughter of lambs reduced the weight of fat and protein and resulted in dehydration, in carcasses.

Fasting, on water, decreased liver weights of cattle transported to an abattoir, relative to those of animals killed immediately, by 10, 15, and 21% for 1, 2, or 3 extra days of fasting, on water (Kauflin et al. 1969); liver weights, relative to hot carcass weights, also decreased during lairage in some groups of cattle fed during this period. Liver weight losses in lambs were 8, 24, and 29%, for 1, 2 and 3 days of fasting, (Warris et al. 1987). Kirton and Patterson (1973) reported weight decreases in the livers of calves fasted for one day of 22% and that over a 3 day period skin weight decreased at about 13% per day.

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). Potential rate of liveweight loss is a function of potential gut fill, relative to liveweight. Thus calves and suckled lambs should lose less liveweight than animals with functioning rumens, grain-fed animals lose less than grazing animals (Ward 1913) and Zebus less than British breeds (Hewetson 1962).

Weather conditions would be expected to influence both live and carcass weight losses, due to both dehydration and tissue catabolism, but microclimates within vehicles are likely to be more important than ambient conditions. Self and Gay (1972) reported liveweight losses of 8.3% in summer and 6.4% in autumn for grass-fed cattle. Degen and Young (1980) reported that exposure to cold reduced liveweight of sheep and cattle by 3 to 7%, largely due to a 50-60% reduction in water intake and losses in fluid from extracellular spaces.

TABLE 1: Effect of duration of access to water, water intake, and muscle water content on carcass weight of steers offered water after a 30-hr journey to an abattoir

Duration of access to water (h)*	Water intake per head (1.)	Carcass weight (kg)	Water content of muscle (% of F.F.D.M.)
0	0	369	76.0
3.5	33	383	77.7
7	33	383	77.5
28	47	381	78.2
32	N.A.	376	78.0
32 + feed	58	379	78.1

* Before a 16 hour period before slaughter without water

Table from Wythes et al. (1980).

Losses in carcass weight would also be expected to increase with increasing temperature, although apart from pigs (Danzer 1970), data are sparse.

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, over and above the effects of the different microclimate on transported animals. Schmalfuss and Kasebier (1978) found greater liveweight loss in cattle transported in unsuitable rail wagons than in cattle transported by road. Transport (1880 km) did not reduce carcass weight more than that which occurred when cattle were subject to similar feed and water deprivation in situ (Holmes et al. 1982) but transported calves lost more carcass weight than calves fasted for a similar period (Phillips et al. 1985).

Hydration status affects carcass weight more frequently and to a greater extent than tissue catabolism. Cattle transported for 30 h and denied access to water before slaughter had carcasses which were 3.8% lighter than those of similarly transported animals allowed access to water on arrival at the abattoir for 3.5 or 7 h prior to a 16 hr preslaughter period with no feed or water (Wythes et al. 1980), see Table 1; the difference was 6% when steers were transported for 27 h and when controls had access to water for 26 h before slaughter (Wythes et al. 1983). Differences in carcass weight were closely correlated with variations in the water content (as a percentage of fat-free dry weight) of muscles (Table 1).

Larger than expected increases in carcass weight, relative to dehydrated animals, have been recorded when animals were given access to water, close to the time of slaughter, after a long period of feed and water deprivation (Wythes et al. 1980, 1983); this is indicative of a temporary overhydration. Although resting and feeding and watering cattle en route to slaughter reduced carcass weight loss somewhat (12.1 v 13.1%, van den Heever et al. 1967; 4.2 v 5.8%, Young 1973) as did providing water and feed in transit (Young 1973) or during lairage at the abattoir (Wythes and Shorthose 1984) they did not prevent it.

Rates of liveweight loss are measured relative to initial liveweights. The potential weight of gut fill, relative to liveweight, is related to a number of factors. As actual weight of gut fill can account for up to 22% of liveweight (Taylor 1954) variations in gut fill at the initial weighing influence the extent of weight loss reported relative to this initial weight. This actual weight of gut fill is affected most by the lapse of time from the last feed or drink. As animals cannot be weighed instantaneously, the order(s) of weighing contribute(s) to variation in weight loss and large numbers of animals are necessary to achieve precision in the estimation of weight loss. Apparent seasonal variations in liveweight loss can arise in pasture-fed cattle when they are weighed at a fixed clock time whereas cattle grazing times are related to day lengths.

Carcasses are dressed differently around the world and even from abattoir to abattoir in the same country. The "standard Australian cattle carcass" now has all udder, or cod fat, the tail, all internal fat (channel fat and kidney fat) removed and some subcutaneous fat trimmed so that losses may differ from situations where other carcass dressing procedures are used. It is difficult to measure carcass weights accurately, because of the impossibility of estimating the, notional, carcass weight of live animals with sufficient accuracy, and of allocating live animals to groups with the same initial carcass weight. Consequently, for adequate precision in estimates of carcass weight loss, large numbers of animals are needed.

PROCEDURES TO REDUCE LIVEWEIGHT, CARCASS WEIGHT AND ORGAN WEIGHT LOSSES

Losses will be reduced by minimising the time animals are off feed and/or water. Siting of abattoirs, the method of marketing (via saleyards or direct to abattoir), and handling procedures can have large effects on national losses. Access to water should be available whenever possible. Optimising microclimates in trucks will also reduce weight losses.

Feeding should increase water intakes. The lack of a large effect of feeding on mean weight loss is, in part, due to total inappetance in some animals induced by the psychological stress (high blood cortisol concentrations) of transport. Sporadic feeding may disrupt the equilibrium of rumen microorganisms, either interfering with the digestive process (Baldwin 1967; Hutcheson and Cole 1986) or increasing the rumen concentrations of pathogens like salmonella (Brownlie and Grau 1976). Hutcheson et al. (1984) recommended K intakes 20% greater, than N.R.C. requirements for normal calves, to maximise gain of feeder calves after transportation. Available evidence indicates that feeding after transport is not economic on the grounds of its effect on carcass weight alone. However, liver weights are increased by feeding (Kauflin et al. 1969). Wilcox et al. (1953) found that appropriate amounts of sucrose (2.7 kg/head) fed for about 30 hours increased dressing percentages and live weights but 5.4 kg of sucrose over this period reduced dressing percentages.

BRUISING

Bruising and associated hide damage are important sources of product loss. Losses occur due to downgrading of bruised carcasses, loss of tissue trimmed from carcasses, condemnation of badly bruised carcasses and the costs of labour associated with this extra processing. Average losses of carcass weight due to trimming of bruised tissue from cattle carcasses have varied over time, and geographically, in Australia from about 0.5 to 0.9% of carcass weight (Anon 1954; Meischke 1975; Wythes and Shorthose 1984). Values reported in New Zealand, c. 2.5%, (Marshall 1977) were greater, whereas those in the U.S.A., about 0.3%, were less (Rickenbacker 1954). Silverside et al. (1987) found that bruise trimming in 5 abattoirs in 3 African countries varied between 0.25 and 0.7% and reported that internationally (10 countries) losses varied between 0.07 and 11.5 kg, with a weighted average of 1.8 kg. In the United Kingdom (U.K.) 10% of all fat lambs were damaged between farm and abattoir; milk fed lambs were worst affected and the problem was worse in lighter lambs. In West Australia ewes arriving at abattoirs via saleyards had more bruising and more were downgraded than ewes consigned directly from farms. Rich (1973) estimated that trimming accounted for 35% of the monetary loss due to bruising of cattle, downgrading of cuts for 21% (C.F. 10% estimated by Anon, 1954), and lost production for 4%. McCausland et al. (1977) found that 30% of 16,400 young calves had bruised stiffle joints. Although there are no Australian reports on the extent of damage caused to hides by transportation, Meischke (1975) reported that areas of linear hide damage were 10 times more prevalent on hides from horned rather than hornless cattle.

It is difficult to establish precisely how and when animals are bruised from farm to slaughter. Korn (1975) in a survey found that each sector of the industry blamed other sectors for bruising animals. Rickenbacker (1954) and McCausland and Miller (1982), respectively, estimated that 70 and 43% of bruising occurred at abattoirs and 20 and 10% before or during transportation.

Horns are an important cause of bruising. Both the prevalence (McManus and Grieve 1964) and weight of bruise trim (Meischke 1975) were about twice as great in horned compared to hornless groups of cattle. Meischke (1975) found that bruise trim was 2.96 kg for horned cattle transported together, 1.84 kg for hornless cattle and 2.73 and 2.34 kg, respectively, for horned and hornless cattle transported together, with the weight increasing as the proportion of horned animals increased. There are conflicting reports on the effects of age/weight on bruising (Rickenbacker 1954; Anderson 1973; Meischke 1975; Yeh et al. 1978). USDA "choice" grade feed-lot cattle had less (0.12 kg/head) bruised tissue trimmed than 'good' or 'standard' grade carcasses and steers were less frequently bruised than cows (Anon 1954; Rickenbacker 1954; Hemsley 1973; Yeh et al. 1978; Wythes et al. 1979); probably reflecting, in part, differences in care related to perceived differences in the value of the animals. Factors which debilitate animals (e.g. undernutrition, disease, advanced pregnancy) increase the severity of bruising because some animals collapse and are trampled by others. Pretransport fasting has been found to increase bruising (Dodt et al. 1979) or have no effect (Bond et al. 1981). Although both overcrowding and loose loading could be expected to increase bruising. available published data do not always substantiate this (Mitchell 1970; McCoy 1972; Anderson and Wythes 1984). Both codes of practice and the transport industry have recommendations on loading densities. These are seldom substantiated and farmers and transporters seldom agree on the appropriate density. The relationship between distance travelled and the extent of bruising in steers and cows transported either by rail or road, or both, is not simple (Wythes, see Wythes and Shorthose 1984). Average extent of bruising appeared to increase as distance travelled increased from 50 to 1200 km and decreased as distance travelled increased from 1200 to 2000 km but there were large variations in the extent of bruising between animals travelling the same distance to slaughter. It could be expected that animals subjected to more handling would have more bruising. However, cattle moved to slaughter via saleyards did not have more bruising than similar animals sent directly to abattoirs (Anon 1972; Horder et al. 1982; Wythes, see Wythes and Shorthose 1984) but were bruised at different sites on the carcass. Transport conditions influence bruising; poor driving, of trains or trucks can increase it. An increased number of stops en route to slaughter increases bruise trim (Meischke 1975).

The design and state of repair of facilities (races, pens, loading ramps and vehicles) influence the extent, severity, and site of bruising. Bruising can occur until animals are exsanguinated (Hamdy et al. 1957; Meischke 1975).

MEASURES TO MINIMISE BRUISING

In the U.S.A.. bruising has been reduced (Anon 1974) by concerted and continuing efforts, of all sectors; involving the determination of the extent of the problem, investigations of causes and the wide advertising of preventative measures. Australian farmers will become more aware of the extent of the bruising problem as it is now a requirement for export abattoirs to record and report, to cattle owners, the extent of bruising. Further, inspection of this abattoir bruising data should allow the identification of problem areas in the marketing chain; these areas can then be examined more cheaply than now. The marketing of only hornless cattle will reduce the loss from bruising. Mixed groups, of horned and hornless cattle, can still be seen in saleyards and abattoirs. The presence of an attendant (drover) on cattle trains can reduce bruising, indicating that increased care reduces bruising. If appropriate "persuaders" (canvas straps or electric goads) are readily available and the use of inappropriate ones (boots, sticks, pipes) forbidden bruising will be reduced. Proper design, use, and maintenance of handling facilities can reduce bruising, but to achieve this it is necessary to educate all those involved in handling stock to the cost of bruising and proper ways of handling animals. Silverside et al. (1987) have questioned the need to trim all bruises; this approach could also reduce the cost of bruising.

BRUISING RESEARCH

There are problems in defining the size of a bruise. Definitions can vary from abattoir to abattoir. To avoid unconscious bias, involved researchers should not be the ones to trim bruises. Results of surveys are often compromised, to varying extents, by confounding, e.g. exhausted animals may be rested longer before slaughter, or valuable animals receive more considerate treatment than animals of lesser value. On the other hand, extrapolations of results of experiments involving small numbers of animals, particularly if they are research station animals, can be misleading.

TRANSPORT STRESS AND MEAT QUALITY

Stress can be defined as an animals response to any demand(s) made on it. In animals transported from farm to slaughter stress responses are induced by water and/or feed deprivation, psychological, physiological, and physical stresses and, most usually, combinations of these factors. If the stress is intermittent and not protracted most animals adjust to it. If the stress is continuous and prolonged, some animals cannot adjust. They become fatigued and may die. The majority adjust, even to continuous prolonged stress. It should be remembered that a doubling in the intensity or duration of the stresses does not necessarily induce a doubling in the animal's response; e.g. muscle glycogen concentration of sheep transported for three hours was 15% greater than that of those transported for one hour (Shorthose, unpublished).

The effects of transport on animals have been assessed in a number of ways. These include:-

- recording the number of deaths;
- measuring microclimates within vehicles determining, usually remotely by telemetry, changes in physiological parameters (e.g. heart rate, respiration rate, body temperature);
- determining changes in blood concentrations of metabolites (e.g. glucose), enzymes (e.g. CPK) and/or hormones (e.g. cortisol);
- determining changes in tissue metabolites, by biopsy, or after slaughter;
- recording changes in conditioned operant behaviours;
- determining meat quality after slaughter.

All of these techniques have problems. Death rates are low, so that to assess effects of different transport treatments properly in a statistical sense many animals (perhaps a million) would need to be monitored. Such surveys suffer problems of confounding previously referred to. Measuring microclimates in trucks is not productive unless differences in microclimate can be related to some tangible stress response. To measure the concentrations of blood constituents of animals in transit it is, usually, necessary to restrain the animal to collect a blood sample. Such restraint is stressful (Stephens and Toner, 1975). The degree of this stress is less in animals used to being handled than it is in naive animals; results from trained or frequently handled, animals, can, thus, only be extrapolated cautiously. If naive animals are bled sequentially during transport, changes in blood constituents with time are confounded with those resulting from the animal's increasing experience with the bleeding process. Collection of blood samples via catheters reduces some of these problems but it is not easy to manage large numbers of catheterized animals and, as all samples cannot be collected instantaneously, order of sampling influences concentrations in a non-random manner. Animals trained sufficiently to be used to determine transport-induced changes in operant conditioning are likely to have different responses from naive animals.

We have used a more pragmatic approach (Wythes and Shorthose 1984). We usually evaluate the effects of farm to abattoir treatments on animals from changes in blood constituents using samples collected at slaughter, and muscle properties, using samples collected after slaughter. This approach has advantages, e.g. blood samples are collected with no additional handling of animals. It has disadvantages e.g. all animals in a transport experiment should be slaughtered at the same abattoir and if treatment groups are not slaughtered on the same day confounding occurs due to "day" effects.

Most of the components of transport stress can be identified. It should be possible to identify their contributions in isolation, and various combinations, to determine the importance of particular factors and perhaps, eventually, allow computer modelling and prediction of effects of changes in components on transported animals.

FEED AND WATER DEPRIVATION

Animals being moved from farm to slaughter in Australia are not usually fed (i.e. they are fasted). Fasting depresses water intake so the hydration status of animals is also affected. Caloric homeostasis is maintained during fasting by gluconeogenesis and the utilisation of fat. In the hind limbs of fasted (6 days) sheep the contributions of acetate and glucose to total oxygen uptake decreased markedly, that of ketones increased three-fold, and that of long-chain fatty acids did not change, relative to those for fed sheep (Jarrett and Ballard 1976). Fasting alone decreases plasma glucose, lactate, citrate, insulin, calcium and magnesium concentrations and body temperature and increases plasma free-fatty acid (FFA), ketone and cortisol concentrations of sheep and cattle. Liver glycogen, muscle glycogen, liver water, and muscle water are decreased and liver lipids and intramuscular lipid concentrations are increased. However, the reduction in muscle glycogen concentration is not usually sufficient to increase the ultimate pH of muscles of fasted cattle or sheep (Howard and Lawrie 1956; Warris et al. 1987).

Generally, the metabolic effects of depriving animals of feed and water, provided the period without water is relatively short, do not differ, qualitatively, much from those of feed deprivation alone. Providing feed and water, but not water alone, for one day, to sheep that had been deprived of feed and water for two days (no transport) increased plasma glucose, insulin, and lactate concentrations and liver glycogen concentrations to those of fed and watered sheep; muscle glycogen concentrations were below those of fed sheep and similar to those of sheep on water alone (3 days) or sheep that had been deprived of feed and water for 2 days and then received water. None of the treatments depleted muscle glycogen concentration below 0.65%.

TRANSPORT STRESS AND ITS EFFECTS ON MEAT QUALITY

After transport, changes in plasma constituents are similar to those occurring during feed deprivation, except plasma cortisol concentrations are, usually, much greater. Although 4 hours of transportation depressed muscle glycogen concentration in sheep (Gire and Monin 1977) sufficiently to increase the ultimate pH values of some muscles, Shorthose (unpublished) found that muscle glycogen concentrations were less after one than 4 hours of transportation. There is agreement that transportation followed by inadequate rest before slaughter decreases muscle glycogen concentrations sufficiently to increase the ultimate pH of some sheep muscles (Markov, E. 1976; Shorthose 1977; Gire and Monin 1977).

In vivo muscle glycogen concentrations in sheep and cattle are, approximately, 1% of the wet weight of muscle. Glycogen concentration at slaughter does not limit lactate production sufficiently to increase ultimate pH of muscles unless it is less than 0.65% (Howard 1963). Thus, if all animals have adequate ()0.65%), rather than normal (1%) muscle glycogen concentrations at slaughter, ultimate pH values will be low (5.4). Wythes and Shorthose (1984) reviewed the effects of the duration and nature of lairage (resting period at the abattoir before slaughter) on the ultimate pH of steers and cows transported to slaughter. The low glycogen concentrations of muscles of exhausted animals can be increased during the resting period at the abattoir but these, potentially adequate, concentrations may be depleted by inappropriate preslaughter handling, thereby nullifying the beneficial effects of rest. Provided both the lairage conditions and preslaughter handling conditions were good, increasing rest with water, or water and feed, available increasingly reduced the mean ultimate pH values of muscles and the prevalence of high ultimate pH values of cattle (Shorthose et al. 1972; Wythes et al. 1980, 81, 82), and domesticated and feral, buffalo (Robertson, Harris and Shorthose unpublished). The provision of feed did not appear to have a large effect on ultimate pH values. The provision of sugar solutions rather than feed (Lapworth, Plasto, and Shorthose, unpublished) also did not decrease mean ultimate pH values more than rest alone did.

MEASURES TO REDUCE STRESS EFFECTS OF TRANSPORT ON MEAT QUALITY

Adequate rest in good lairage conditions will allow cows, steers, and sheep to restore muscle glycogen concentrations to levels which are sufficient to ensure low ultimate pH values, provided the handling of animals from resting pens to slaughter is reasonable. If conditions during the period at the abattoir are not good, e.g. animals exposed to cold, wet, and windy conditions, resting will not necessarily be beneficial. Young calves and sucker lambs do not benefit, and the pH values of their muscles are usually increased, by long periods of rest at abattoirs (Buchter 1975).

Resting animals in the course of a long journey to slaughter has a beneficial effect on muscle ultimate pH values and rest en route and at the abattoir have a beneficial, additive, effect; there was a significant (r = -0.71) correlation between total hours of rest (en route and at abattoir) and the percentage of high ultimate pH carcasses (Wythes et al. 1988).

WEATHER

Animals in transit are constrained from displaying normal behaviour patterns that reduce the effects of exposure to inclement weather. In hot weather they cannot seek shade, and, particularly when vehicles are stationary, may suffer high solar radiation loads. Alternatively, in cold weather air movement can result in very low effective temperatures and animals can suffer greater rates of heat loss than animals at pasture. Greatest rates of heat loss occur when animals are wet. The effects of inclement weather are greater when they are unseasonal. Unseasonal cold spells during autumn or spring when animals either have not grown, or have shed, their winter coats, are likely to be more deleterious than similar, seasonal, weather in mid-winter.

Vehicle construction determines the microclimate that animals are subjected to. Usually, in Australia, vehicle design is such that conditions within cannot be varied from summer to winter. This is not the case in some other countries.

The effect of temperature on animals is influenced by their body condition and the level of their recent feed intakes; fasting cattle raised in a temperate climate have a critical temperature of 18°C, animals fed to maintain weight one of 6°C, and fattening animals one of 1°C.

Adverse weather increases the prevalence of high pH (dark-cutting) meat in cattle (Munns and Burrell 1966; Tarrant and Sherington 1980), and the prevalence of dark-cutting meat in sheep (Furnival et al. 1977) and cattle (Shorthose 1980) increased as daily temperature minima decreased. High temperatures have also been reported to increase the prevalence of high pH meat in cattle (Cervenka 1969) but this effect was not observed in a survey, over a one-year period, in S.E. Queensland (Shorthose, unpublished).

DEATHS, CRIPPLING AND DEBILITATION

There are few published reports on factors which can kill, cripple, or debilitate cattle or sheep in transit. In one Queensland abattoir, cattle deaths in transit from 1958-9 to 1967-8 decreased from 0.7 to 0.2 per cent, but sheep deaths did not change (Shorthose 1980). More recently a study of cattle transported by train in Queensland

TABLE 2: Annual percentages of sheep and cattle dead in transit to one Queensland meatworks over an 11 year period and the effect of reduced annual rainfall

Annual rainfall as a percentage of 30 year average	Percent sheep dead	Difference from average	Percent* cattle dead	Difference from average
70%	1.63	+ 38%	0.54	+ 23%
100%	1.18	0	0.44	0
130%	0.74	- 38%	0.32	- 23%

* Adjusted for decrease in deaths with time

indicated that 0.1% died in transit and a further 0.26 within 24 h of arrival (Anon 1981). Deaths were greater in females than steers. They decreased when an attendant accompanied the animals in transit. In Queensland, cattle deaths increased as ambient temperatures increased.

It could be expected that animals in poor body condition would not survive transport as well as fit animals.

However, producers do not willingly send cattle that do not meet market requirements to slaughter. It was found that the annual rate of deaths of sheep and cattle in transit to a meatworks increased as rainfall for the year decreased below average, see Table 2.

When annual rainfall was 30% below average sheep deaths increased by 38% and cattle deaths by 23%.

The stress of transportation and lack of feed and water may produce metabolic disturbances directly or induce disturbances in the gut environment which may lead to an increase in pathogenic organisms which, in turn, could further disturb electrolyte balance and precipitate electrolyte and metabolic disorders. It is unfortunate that in studies of diseases associated with transport, metabolic disturbances are usually ignored and in studies of stress and metabolic disturbances in transit, disease aspects are ignored.

Animals in transit to meatworks are stressed, can be in infected environments and, particularly if they pass through saleyards, can be in contact with diseased animals from other herds. Transport stress interferes with animal's immune systems (see Hails 1978).

Shipping fever is a broad syndrome which occurs, in N. America, most frequently in store cattle fatigued by long periods of transport. It is an acute infection characterized by, fever, bronchopneumonia, and, less often, gastroenteritis. Undoubtedly stress and metabolic disturbances are important factors in this syndrome. It has been suggested that the primary infection is viral and that bacteria (e.g. Yersinia spp.) play an important secondary role (see Hails 1978).

Seddon (1965) reported that outbreaks of salmonellosis were most commonly associated with transportation of animals over long journeys. Infection can occur from infected trucks, infected yards or infected animals. Brownlie and Grau (1976) showed that Salmonella survived better in the rumen of starved animals because volatile fatty acid (VFA) concentrations there were less and their inhibitory effect on the growth of Salmonella and other Enterobacteriaceae was less than that in fed animals. Sporadic feeding also increased the numbers of Salmonella in the rumen

Hypocalcaemia or "transport tetany" is often considered a major cause of losses of stock in transit, although few reports mention concentrations of blood constituents in affected animals, or similarly-treated, but unaffected, animals. Transport can induce subclinical ketosis, in wethers and non-pregnant ewes (Groenwald et al, 1941) and pregnancy toxaemia, in pregnant ewes (Sutton and van den Heever, 1968). The 'liver disease' which occurred in heifers transported for more than 2 days (Glawischnig et al. 1972) was only a greater-than-normal increase in liver lipid concentration; a normal response to feed deprivation in cattle and sheep.

Shorthose and Shaw, 1977, examined the plasma concentrations of 100 sheep that were down and unable to stand at meatworks ("downers") and from 100 normal sheep. Samples were not collected from animals in extremis nor from animals with limb fractures.

Although 23% of normal sheep had plasma calcium concentrations, less than 9 mg/100 ml, at slaughter, the frequency was greater (65%) in the "downer" sheep. 11% of the "downer" sheep were considered to be hypocalcaemic. Differences in plasma magnesium concentrations between "downer" and control sheep were less but 8% of the "downer" sheep and none of the normal sheep were considered hypermagneseamic.

In 200 cows on arrival at a meatworks, 23% were hypocalcaemic, 34% hypomagnesaemic, and 13% had both hypocalcaemia and hypomagnesaemia (Warnock et al. 1978). Cows with low serum calcium concentrations were more likely to collapse than animals with greater serum calcium concentrations. Serum magnesium and inorganic phosphorus concentrations were not different in "downer" and ambulant cows. Serum calcium and serum magnesium concentrations generally decreased with increased periods of starvation. Cows pregnant for more than 6 months maintained magnesium serum concentrations over the period of feed deprivation and had very low serum calcium levels on arrival, but, unless they became "downers", had serum calcium levels similar to those of other cows after 3 days off feed at the meatworks.

Most non-pregnant ruminants in a non-stressful situation can survive feed deprivation, provided water is available, for a considerable time. However, the psychological stress associated with putting fat sheep into pens indoors is sufficient to disturb some of them such that they do not eat and they often die (Reid, 1968). Again, if pregnant sheep, particularly ewes carrying two lambs, are deprived of food or exposed to cold late in pregnancy they will become ketotic and some will die. The stress of transport and feed deprivation combine to impose considerable stress on the ability of animals, particularly pregnant ones, to maintain normal carbohydrate metabolism.

Groenwald et al. (1941) and Sutton and van den Heever (1968) have reported ketosis, in wethers, and pregnancy toxaemia, in pregnant ewes, transported long distances by rail.

CONCLUSION

Moving animals from farm to slaughter is an important phase of meat production, one which can have large effects on the yield and quality of meat. Improvements are unlikely to occur quickly until all involved are aware of the extent of losses, the causes of these losses, and ways to minimise them. Time from farm to slaughter influences the degree to which animals are stressed and the yield and quality of product. It is important, therefore, that the siting of abattoirs be evaluated rationally (see Drynan and Brown 1983). Computer assisted livestock marketing (animals are sold by description, on a computerised selling network, before they leave the farm) reduces both the handling of animals and time from farm to slaughter. Direct marketing, from farm to abattoir, is logistically simpler, and reduces the time from farm to slaughter.

Stock handlers need to know the proper way to handle animals. Animal handling facilities need to be designed by individuals knowledgeable in the ways of animals and animal handling and to be meticulously maintained. Drivers of vehicles carrying animals should know the cost of bruising which results from an abrupt halt. Although animals need to be inspected en route, the duration of these stops should be short, and the stops not too frequent. Animals should be protected from the extremes of weather; this implies proper truck and pen design. Loading densities should be appropriate and uninterrupted journeys not too long. 'Persuaders' should be effective and designed not to damage or unduly stress animals. Animals which are unfit to travel should not be transported.

Adequate rest at abattoirs can restore exhausted animals but inappropriate handling from resting pens to slaughter can undo any benefits of this rest.

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