PRESLAUGHTER STRESS - EFFECTS ON THE YIELD AND QUALITY OF MEAT

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SUMMARY

During the marketing of slaughter stock, product weight and quality can only decrease. There is, however, little published information on these losses.

In this paper an attempt is made to assess the various components of these changes and quantify the extent of overall loss which can occur when cattle or sheep are marketed. Carcass and organ weight losses, bruising, deaths, and condemnations are considered. Variations in the appearance, eating quality, and hygienic status of meats related to events during marketing and slaughter are also described.

To minimise losses it is necessary first to understand the effects of contributory factors and how these interact with one another. Understanding causes will not minimise losses. To reduce them it is necessary that those whose actions can influence losses are properly informed. It is possible, for example, that the correct siting of abattoirs, or improved design of stock handling facilities, or decreasing the duration of rail journeys may be more effective than the resting of cattle in transit or the redesigning of cattle wagons.

INTRODUCTION

Animals destined for slaughter are a delicate product. Deterioration during marketing reduces both the quantity and quality of the meat for sale. It is the task of everyone concerned with the marketing of livestock to minimize such losses, whether they are producers, transporters, stock agents, meat processors or meat scientists; as all benefit. Part of our task, as meat scientists, is to disseminate new knowledge to those able to implement better ways of marketing animals.

Between the farm and slaughter, cattle and sheep are subjected to transportation, confinement, unfamiliar surroundings and additional handling. They are without feed and water for various periods. Collectively or singularly, these and other factors can constitute pre-slaughter stress. The commercial consequences include

(i) death and crippling of animals,

(ii) reduction in carcass weight through catabolism, dehydration, bruising and condemnation of whole carcasses, sides or quarters, and

(iii) impaired meat quality as indicated by high muscle pH values, tougher and darker meat, and poor keeping quality.

STRESS

Stress is an imprecise term, but can be defined as an animal's response to any demand made upon it. It is generally accepted that animals vary in their susceptibility to stress.

Stress responses are induced by feed and water deprivation, and physical and psychological stresses, as well as by any combination of these factors. If the stress is intermittent or not protracted, most animals adjust to it. If the stress is prolonged, some animals may be unable to adjust; they become fatigued and may die. The majority will usually adjust to prolonged stress. Increases in the duration or intensity of stresses do not necessarily induce similar increases in the metabolic state of stressed animals. For example, the muscle glycogen concentration of sheep transported for three hours is 15% greater than that of those transported for one hour.

DEATHS, CRIPPLING AND DEBILITATION

There are few published reports on factors which influence the incidence of death, crippling and debilitation of cattle and sheep in transit to meatworks. A recent survey by the Queensland

Meat Industry Organization and Marketing Authority (QMIOMA) found that 0.1% of cattle died during rail journeys. This percentage increased to 0,36% when deaths within 24 hours of completing the journey were included. In an earlier CSIRO survey from 1958-59 to 1967-68 cattle deaths in transit decreased from 0.7 to 0.2%. There was no obvious trend for sheep and lambs, with deaths varying from 2.2 to 0.61%. The much greater mortality among sheep may be due to their greater susceptibility to stress, less care of individual animals or a combination of these and other factors.

Type of animal. The type of animal seems to be important, since QMIOMA found that deaths were most common among bulls, more females died than steers or yearling cattle and more store than fat cattle died. It is commonly believed that pregnant cows and ewes are most at risk. When it is essential to transport weak and drought-affected animals, they require additional care in transit (Table 1).

TABLE 1: ANNUAL PERCENTAGE OF SHEEP AND CATTLE DYING IN TRANSIT TO ONE QUEENSLAND MEATWORKS AND THE EFFECT OF ANNUAL RAINFALL

Annual rainfall as a percentage of 30 year average	Sheep		Cattle†	
	Incidence (%)	Difference from average	Incidence (%)	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 trend over time.

W.R. Shorthose (1980) 3rd National Symposium on the Science and Technology of Meat, Buenos Aires, November 1980.

Handling. The care and attention which livestock receive influence the mortality rate, as fewer cattle died when accompanied by a train drover than when unaccompanied (QMIOMA survey). However, the presence of a drover had a similar effect for both fat and store cattle. Loading cattle at the correct density and segregating them on size and sex will reduce mortalities.

Weather: Extreme weather conditions increase deaths, although these effects may be modified by the physical attributes of the animal. Wind reduces the effective air temperature considerably, e.g. a wind of 60 km.p.h. reduces a still air temperature of 20°C to an effective air temperature of 0°C. The combination of cold and rain is even more detrimental. Cold, wet, windy weather will have a greater effect on

the heat loss from recently shorn sheep than from cattle with a long winter coat. The effect of cold increases as the time animals have been without feed increases. Stock deaths also increase in hot weather.

Distance. Many cattle and sheep are transported long distances in Australia and are unable to reach their destination in one stage. Instead it is necessary to interrupt their journey so that they can be rested, fed and watered. There is no information on the optimum frequency and duration of resting periods relative to the total length of the journey. QMIOMA found that cattle deaths increased only when transit periods exceeded 36 hours. Consequently they recommend that cattle are rested every 36 hours, unless the journey will be completed with only a few hours of additional travel.

Disease. It is unfortunate that in studies of diseases associated with transport, stress and metabolic disturbances are usually ignored, and vice-versa. Nevertheless, animals in transit to meatworks are stressed and can be in infected environments or mix with diseased animals from other herds. Hypocalcaemia or 'transport tetany' is frequently presumed to be the major cause of losses of stock in transit, often without any knowledge of the blood electrolyte concentrations of animals. However, transportation plus feed deprivation imposes considerable stress on the ability of animals to maintain normal carbohydrate metabolism. It is likely that many animals are often experiencing disturbed carbohydrate metabolism rather than disturbed electrolyte balance. Healthy animals are less of a risk than those in poor health, or pregnant ones.

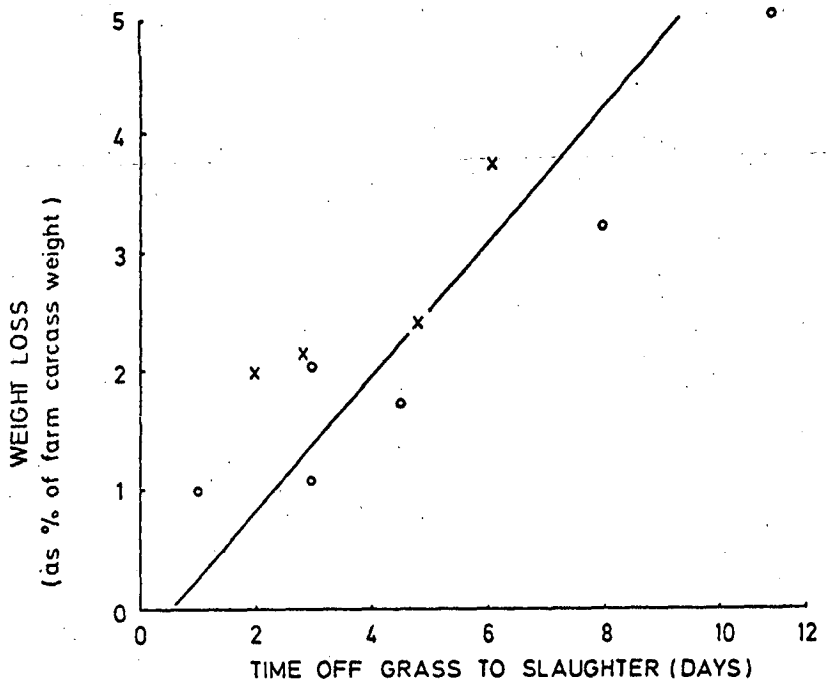
LOSSES IN CARCASS WEIGHT

Loss of carcass weight can result from dehydration and tissue catabolism, with the loss increasing the longer the animals are without water and feed. The trimming of bruised tissue from the carcass reduces its weight. The condemnation of quarters, sides or whole carcasses is another source of loss.

Although losses in carcass weight reduce the nation's beef production, there have been few studies to document the extent of weight losses or ways to remedy them. No attempt has been made to quantify the monetary loss. It is difficult to determine accurately the effect of different transport and marketing conditions on the extent of losses in carcass weight, as 'initial' carcass weights are not known accurately. It is difficult to allocate live animals into subgroups so that the average carcass weights of subgroups are similar (within 1% of each other). This problem can only be overcome if large numbers of animals are used.

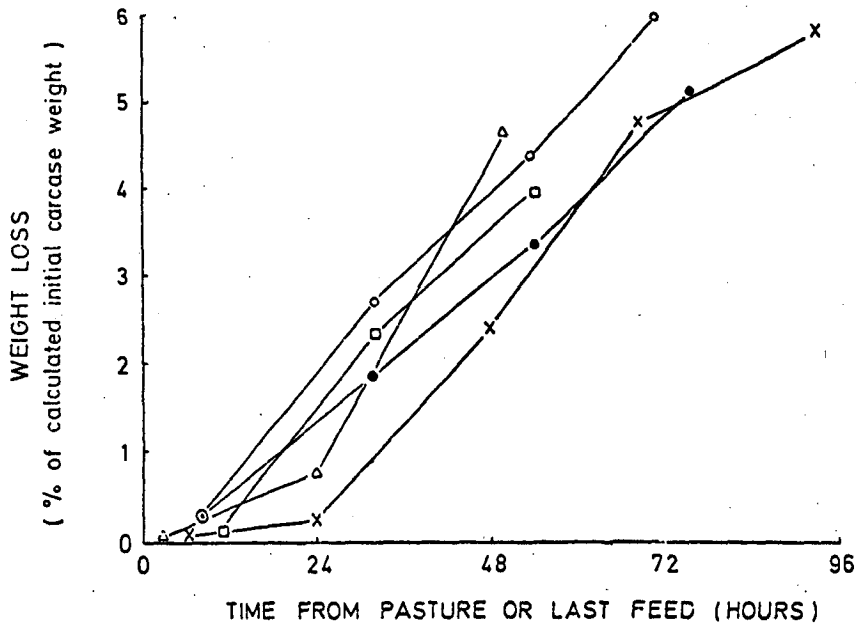
Time. In cattle, estimates of the daily rate of carcass weight loss range from 0.75% of estimated 'on farm' carcass weight for animals deprived of feed and water for 4 days to 0.3 to 0.5% for

cattle given occasional access to feed and water over a 3 to 11 day period (Fig.1). Sheep and lambs deprived of feed and water lose approximately 1.5% of estimated 'on farm' carcass weight per day during the first 4 days off feed (Fig.2). Carcass weight loss appears to commence about 12 hours after last feed.



CARCASS WEIGHT LOSS OF CATTLE IN TRANSIT TO MEATWORKS

FIG.1



CARCASS WEIGHT LOSS OF SHEEP

FIG.2

W.R. Shorthose (1970); In "Commercial Aspects of Prime Lamb Production", N.S.W. Dept. of Agric., Cowra.

During transportation animals are deprived of feed and water, as well as being subjected to extra handling and the ordeal of travelling. The available evidence for cattle suggests that the total journey time is more important than the distance travelled. There is little additional effect due to the travelling itself. For example in northern Queensland, cows transported 460 km and slaughtered three days after mustering had a mean carcass weight of 230 kg. Another group held at the same abattoir for a further five days dressed 225 kg, as did a third group transported a further 1,595 km to a different abattoir and also slaughtered eight days after mustering.

One of the major criticisms of the saleyard system is that it prolongs the marketing process. In Queensland studies, cattle consigned directly to the abattoir, offered water and slaughtered next day had heavier carcasses than those slaughtered two days later. In Western Australian studies, cull ewes consigned directly to the abattoir had an average carcass weight of 19.2 kg whereas those from the saleyard and slaughtered the following day averaged 18.3 kg.

Access to water. All animals should have access to water whenever possible, especially at the meatworks, to minimize the possibilities of stress and their carcass tissues being dehydrated at slaughter. Dehydrated cattle have lighter carcasses than animals that receive water (Table 2). Nevertheless, access to water does not wholly prevent carcass weight losses. In a number of experiments, offering animals feed did not slow carcass weight loss more than when animals were offered water only. Not all animals will eat and drink in these situations.

TABLE 2: EFFECT OF REHYDRATION ON MEAN CARCASS WEIGHT OF BULLOCKS AFTER A LONG JOURNEY

Group	Water Intake (L)	Carcass weight (kg)	Water content of muscle (%)
No water or feed	0	369	76.0
3.5 h on water	33	383	77.7
7 h on water	33	383	77.5
28 h on water	47	381	78.2
32 h on water	NA	376	78.0
32 h on water and feed	58	379	78.1

NA = Not available, because water meter broke down.

J.R. Wythes, W.R. Shorthose, P.J. Schmidt and C.B. Davis (1980). Australian Journal of Agricultural Research 31:849.

Ways to reduce losses in carcass weight are: 1. The time from farm to slaughter should be as short as possible, 2. Animals should have access to water whenever possible.

BRUISING

Bruising has been a major problem in the meat industry for many years. The major obstacle in reducing these losses is the inability to determine when the bruising occurred and so apportion responsibility for the damage. Even when it is possible, there is debate as to whether control should be exerted by imposing financial penalties or by advertising and persuasion.

There is a tendency for the various sectors of the industry to abdicate individual responsibilities. This is illustrated by a survey in southern New South Wales, when producers, transport operators, stock agents and abattoir management were asked to rank the causes of bruising in order of importance.

TABLE 3: RELATIVE RANKING OF CAUSES OF BRUISING
(1 = greatest cause, 9 = least cause)

Bruising due to:	Producers	Stock Carriers	Stock Agents	Meatworks Managers
Presence of horns	1	2	3	5
Facilities, handling on the property	3	1	4	3
Transport, distance and handling	1	8	1	1
Handling at the saleyard	4	4	5	2
Handling at the meatworks	8	6	8	9

T.J. Korn (1975). Agricultural Gazette, N.S.W. 86(1):3.

In early studies of bruising in cattle, bruise trim ranged from 0.68 to 7.35 kg per carcass, with an average of 1.88 kg per carcass. However, in a recent survey of 35,000 cattle in southern Queensland, the average was 1.0 kg trim per carcass, with 0.12% of carcasses being condemned because of extensive bruising. Studies in Victoria and New South Wales revealed a condemnation rate of 0.03%. Studies in Western Australia showed that bruising was a major reason for rejecting sheep carcasses for export.

There are no published estimates of the financial losses resulting from damage to hides when cattle are trucked from farm to slaughter. Hide damage is more prevalent among horned than hornless cattle.

Horns. Despite the overwhelming evidence that horns are a major cause of bruising (Table 4), horned cattle continue to predominate among sale consignments, whether animals are sent to saleyards or directly to meatworks. In addition, these horned animals are almost always mixed with hornless stock. Perhaps this is because there is little incentive? We believe that the avoidable bruising caused by horns will not cease until penalties are imposed and producers have a direct financial incentive to sell only hornless cattle. The tipping of horns is ineffective against bruising and dehorning of adults cannot be justified.

TABLE 4: EFFECT OF HORNS ON BRUISING IN CATTLE

	Horned groups	Mixed groups		Hornless groups
		Horned animals	Hornless animals	
Average weight of bruise trim kg	1.88	1.82	1.48	1.04

Source: F.D. Shaw, R.I. Baxter and Ramsay, W.R. (1976). Veterinary Record 98:255.

Type of animal. The characteristics of individual cattle seem to be more important than genotype in determining susceptibility to bruising. Because cows bruise easily, they require more careful handling than steers or bulls. Animal-related factors appear to determine the severity of bruising whereas other factors affect where bruises occur on the carcass.

Handling and transport. Many of the people, who handle, transport and oversee the movement of stock between farm and slaughter, are unaware of the consequences of their actions and designs. In addition, published information on proper ways to handle animals seldom reaches those responsible for these tasks - for example stockmen, saleyard operators, road transporters, railwaymen and the designers of stock crates and yard facilities. Variations in bruising between groups of animals handled through the same facilities or transported on similar road vehicles and railway waggons indicate a lack of uniformity in skills and care. Few Australian facilities exploit the behavioural characteristics of cattle and sheep. Careful attention to the overall design of these facilities and constant attention to their repair results in a smoother flow of animals, fewer man-animal confrontations

and less bruising. Similarly, few vehicles, stock crates and railway waggons are designed and constructed with a view to minimizing bruising and stress.

Contrary to popular belief, bruising does not necessarily increase with distance travelled or duration of journey for steers and bullocks, although it may for females. Average loading densities have evolved for cattle of various sizes in different types of railway waggons and road transports. Standardisation of stock crates would assist in developing specific densities, and so improving the welfare of stock in transit. There are difficulties also in complying with these densities, because animals can vary greatly in size within a given liveweight range. The meagre evidence showed no effect of loading density on bruising.

Method of sale. Animals sold at saleyards are subjected to more handling, including at least one more loading and unloading, than those consigned directly to meatworks. Although the extra handling does not necessarily increase bruising, the potential still exists. Yet in a number of Queensland studies, similar average bruising in cattle has been reported for both methods of sale. In addition, hornless cattle are mixed with horned animals, presumably because there are insufficient yards for each buyer to keep hornless cattle as a separate group. In a Western Australian study, ewes from saleyards had 1.5 to 2.0 times more bruising at particular carcass sites than animals sent direct to the meatworks. Twenty-three percent of saleyard carcasses were rejected for export because of bruising compared with 17% of direct consignment animals.

At the meatworks. Animals can be bruised at the meatworks. Bruising can occur up until the time animals are bled; in this regard it should be noted that knocking box designs are often inappropriate. Bruising occurs more on the side of the beef carcass that hits the floor when stunned animals roll from the knocking box. The severity of these bruises increases as the time from stunning to bleeding increases.

Ways to reduce the incidence and severity of bruising are:

1. Encourage producers to market only hornless cattle and not mix horned and hornless stock.

2. Ensure that extra care is used when marketing cows.

3. Minimize handling and the time from farm to slaughter.

4. Ensure that all handling and transport facilities are well-designed and kept in good repair.

5. Ensure that all handlers are aware of the proper way to handle animals and of the cost of bruising.

CONDEMNATIONS

There is little information on factors affecting the incidence of condemnations of carcasses at meatworks. 'Emaciation' is probably a frequent cause of condemnation of cattle and sheep carcasses. In a study at one Queensland meatworks, condemnations were greater in years of below-average rainfall than in years of above-average rainfall. From 1964 to 1968, the average rate was 0.2% (range 0.10 - 0.31%) for cattle and 0.65% (range 0.26 - 1.11%) for sheep. For one year only at two meatworks in Western Australia, condemnations averaged 5.6% for sheep, and 0.8% for sheep and 0.07% for cattle, respectively.

MUSCLE pH

Ultimate pH is related to tenderness, colour, flavour, acceptability, water-holding capacity and keeping quality of meats. Many factors on the farm, during transportation and selling, and at meatworks can influence muscle glycogen content at death, and in turn ultimate pH and meat quality.

The amount of glycogen present in the muscle at slaughter influences the amount of lactic acid produced in muscles after death. In turn, this determines the ultimate pH of a muscle. If a healthy, well fed, unstressed animal is slaughtered, about 1% of the wet weight of the muscle will be glycogen and the ultimate pH will be 5.4-5.5, with some glycogen still left in the muscle. It is not until the muscle glycogen content is less than about 0.65% at slaughter, that glycogen content starts to limit the ultimate pH. A glycogen content of 0.5% means an ultimate pH of about 6.1. An absence of glycogen in the muscle at death produces an ultimate pH of about 7.2. Thus healthy, well-fed animals can tolerate stress which depletes muscle glycogen by about 40% before the ultimate pH of their meat is increased above normal.

Meat is 'dark cutting' when the muscles have a low acid content and so high ultimate pH. Domestic consumers prefer not to buy this, believing it comes from old animals, will be tough and not keep for long. However, high pH meat is preferred for the manufacture of some sausages, as it binds water and fat better than meats of a lower pH. It is generally agreed that meat with a pH above 6.0 should not be vacuum-packed, because bacteria grow more quickly on high pH meat. Some bacteria (e.g. Alteromonas putrefaciens) can produce hydrogen sulphide that at high pH reacts with myoglobin to produce undesirable green sulphmyoglobin.

If the pH of the M.longissimus dorsi (LD) is 5.8 or less 24 hours after slaughter, usually no muscles in the carcass have an ultimate pH above 6.0. Alternatively, if pH measurements are used to prevent dark meat being displayed in retail outlets, the maximum acceptable ultimate pH values of individual cuts should be variable as consumers usually purchasing beef from pasture-fed animals consider meat with pH greater than 5.9 to be dark, while those usually buying feedlot beef consider meat above pH 5.7 to be dark.

Type of animal. Bulls and cows are more likely to produce meat with a high ultimate pH than steers or heifers. This difference may be due, in part, to the greater age of bulls and cows. However, there is evidence that bulls have slightly higher ultimate pH values than steers of the same age. It could be anticipated that heifers in oestrus would have a greater incidence of dark-cutting meat than other heifers or steers.

Cattle fattened on pasture are usually handled less frequently than animals from feedlots. A CSIRO survey of 3,000 animals showed that feedlot cattle generally had a lower incidence of dark-cutting meat than animals off pasture. However, high incidences of dark cutting can occur in both pasture-fed and feedlot cattle.

The available evidence shows that Zebu cattle do not have a higher incidence of dark cutting meat than British breeds.

Disease. Animals with overt symptoms of disease are not knowingly slaughtered for human consumption. However, animals with sub-clinical infections or recovering from diseases at slaughter will have a greater incidence of dark cutting. Some diseases, which cause muscle paralysis (e.g. ephemeral fever or three-day sickness), cause recovering animals to have muscles with widely differing ultimate pH values, some high and some normal.

Time and rest. The time taken to move animals from farm to meatworks may be as short as one hour or as long as ten days. Stress during this time tends to reduce muscle and liver glycogen concentrations. Some animals are unable to cope with stress and their energy reserves are so depleted that they become exhausted, and a few may die. Consequently all animals are held for at least 24 hours at the meatworks, in an attempt to allow them to recover and replenish glycogen before slaughter. Although it is presumed that animals rest, not all holding pens provide a quiet, undisturbed environment that permits genuine rest.

Long journeys are undoubtedly stressful and if animals are killed before they have recovered, they will have higher-than-normal ultimate pH values. For example in one study, 45% of cattle rested for only 2 days after a 1,300 km journey had LD muscles with ultimate pH values greater than 5.8, but only 7.5% of those rested for 4 days. Similar results have been obtained with sheep.

In a survey of 6,400 cattle, the incidence of carcasses with high pH values increased as the time from farm to slaughter increased (Table 5). The time in transit from farm to slaughter can be reduced if roads, railways and vehicles are improved.

TABLE 5: EFFECT OF TIME FROM FARM TO SLAUGHTER ON THE INCIDENCE OF CARCASSES WITH LD pH VALUES 24 h POST MORTEM GREATER THAN 5.7

Time from farm to slaughter	Number of cattle	High pH values (%)
Less than 1 day	2,850	6
1 day	3,290	10
2 days	190	20
>5 days	70	25

Source: W.R. Shorthose (1980). 3rd National Symposium on the Science and Technology of Meat, Buenos Aires, November 1980.

Method of sale. Sending animals to a meatworks via a saleyard increases the time from farm to slaughter, the time without feed, the amount of handling and chances of animals being damaged and/or stressed. In a survey of 7,600 cattle, twice as many animals from saleyards had ultimate pH values above 5.7 as animals sent directly from farm to meatworks (22% v 10%).

Weather. Cold weather can increase the ultimate pH of lamb muscles, even if the lambs are only removed from pasture 24 hours before slaughter. Similarly, low overnight temperatures increased the incidence of dark-cutting meat in feedlot cattle which were slaughtered 1 or 2 days after their last feed. Fed animals are more resistant to cold, stress and disease than animals deprived of feed or receiving lesser amounts of feed. There is some evidence that abnormally high temperatures increase the incidence of dark-cutting meat.

Handling and pre-slaughter stress. Handling and psychological stress close to the time of slaughter deplete muscle glycogen in cattle and sheep. In large groups of animals, the order of kill appears to have an effect. In a CSIRO survey 5% of the first cattle killed had an ultimate pH greater than 5.7 compared with 25% of the last animals. Within groups, the first animals to enter the race to the knocking box or those remaining alone in the race are more likely to produce dark meat. Animals that, subjectively, appeared to be upset during handling immediately before slaughter also tended to have muscles with higher ultimate pH values. Yet others that were not considered to be disturbed also had dark meat.

Stress can be reduced if handling facilities, yards and races are designed to exploit the particular behavioural traits of the species being killed. A smooth flow of animals rather than a sporadic one tends to reduce preslaughter stress. Electric goads should be used sparingly.

Stress immediately before slaughter is detrimental to meat quality because animals do not have time to restore muscle glycogen levels. If animals which already have lower levels of muscle glycogen are subjected to relatively mild stress the effect on meat quality can be large. If animals are wet, due to rain or washing procedures, and exposed to wind, in cold weather, they will shiver. Shivering rapidly depletes muscle glycogen concentrations and can result in dark cutting meat.

Ways to reduce the incidence of dark cutting are:

1. Minimize time from farm to slaughter
2. Careful handling
3. Adequate rest before slaughter
4. Minimize pre-slaughter stress
5. Avoid exposure to inclement weather
6. Ensure all handling and transport facilities are well designed.

COST OF LOSSES - WHAT CAN WE AFFORD TO DO?

We estimate that the annual cost of deaths and bruising to the cattle and sheep industries were of the order of $36,000,000 and $32,000,000, respectively, in 1980. It is realistic to suggest that these losses can be halved. How much can we afford to spend in order to save this $34,000,000 per annum? How should it best be spent?

We believe that there are deficiencies in basic knowledge in this area, requiring research to improve the handling, transport, facilities and management of livestock along the marketing chain. The evaluation of available statistical information is necessary to establish base losses (for example, causes of condemnations), and thereafter to measure the effects of adoption of new techniques. Strategies to educate stock handlers need to be evaluated, before any effective publicity campaign can be implemented.

CONCLUDING REMARKS

If losses due to preslaughter stress in carcass yield and meat quality are to be minimized in cattle and sheep, it is necessary first to understand the effects of contributory factors and how these interact with one another. However, simply understanding causes will not minimize losses. To reduce them it is essential that those whose

actions can influence losses are properly informed and that adequate finance is available for this. The task of effectively relaying this information is the responsibility of meat scientists, extension officers and other organizations with an interest in livestock and meat marketing. However, if penalties or incentives are to be successful, they need to be applied universally and rigorously.