HANDLING AND TRANSPORT OF MEAT ANIMALS IN RELATION TO EFFICIENCY, MEAT QUALITY AND WELFARE

INTRODUCTION

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The harvesting process begins with the removal of the animal from food and water, progresses through a variety of handling and transport procedures that culminate at the abattoir where the animal is slaughtered and the carcass processed for sale to either the local or export market. The manner and method in which this harvesting process is carried out can significantly affect the returns to the industry.

The handling and transport of animals can lead to stress, bruising and in some cases more serious injury or death. Stress can have a deleterious effect on the colour, texture and keeping qualities of the meat and consumer acceptability, while bruising often requires the most expensive cuts of meat to be trimmed or discarded and sometimes the condemnation of the whole carcass. Consequently, there is a need to review current handling and transport procedures, particularly in relation to carcass quality and the welfare of cattle, sheep and pigs. Improvements in welfare during handling and transport procedures will improve productivity and help reduce losses associated with poor carcass quality.

THE HANDLING AND TRANSPORT OF LIVESTOCK IN RELATION TO MEAT QUALITY

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The movement of livestock from the farm to an abattoir involves exposing animals to unfamiliar surroundings, different stockmen, strange noises and smells, plus the rigours of transportation. Many animals are unaccustomed to confinement. This paper outlines broadly the effect of handling and transport on meat quality, including bruising of cattle, sheep and pigs.

When consumers assess meat quality, most rank tenderness before juiciness and flavour. In carcasses, muscle pH and colour are indicators of tenderness. Water-holding capacity and keeping quality are related to pH. When muscle glycogen concentrations are adequate at slaughter, pH falls from about 7.2 to 5.5 during rigor mortis. Given good meat processing procedures, muscle should be most tender at pH 5.5 with beef, lamb and mutton having a bright cherry-red colour whereas pork is a salmon pink because of its lower myoglobin content. Because muscle glycogen concentrations determine the extent of the decrease in pH, substantial reductions in concentrations in the live animal result in high pH values, i.e. 6.0 or above, 24 h post-mortem. This muscle is tough to "mushy" and much darker in colour, with pork being described as dark, firm, dry (DFD) and beef as dark cutting. If the pH drops very rapidly while the meat temperature is still high, muscle proteins are denatured; the resulting exudate masks the myoglobin to give a pale, soft, exudative (PSE) appearance. PSE is seen mainly in pigs. Dark cutting beef is aesthetically unacceptable to consumers and is unsuitable for vacuum packaging, while PSE pork is difficult to cure correctly.

Stress produces a number of physiological changes, one of which is a reduction in muscle glycogen concentrations. Animals vary in their susceptibility to stress, with some strains being badly affected; an example is the Pietrain

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breed of pigs. The detrimental effects of stress on meat quality are more frequent in entire males than in other animals. While the majority of animals can adjust to some degree to prolonged stress, some individuals cannot, become fatigued and die.

When an animal is injured through trauma, blood from the ruptured blood vessels penetrates the surrounding tissues causing bruising. Bruised tissue is usually trimmed from the carcass, reducing carcass weight and in cases of severe bruising, the carcass may be down graded or condemned. Although bruising occurs in all species, it is seen most frequently and extensively in cattle. Individuals vary in susceptibility and among cattle, females bruise more than steers (Yeh et al. 1978).

Since horns account for about half of all bruising in horned cattle (Meischke et al. 1974; Shaw et al. 1976), cattlemen should dehorn calves or breed polled animals. Dehorning is done most conveniently at branding or weaning and at this stage, it causes only a temporary setback to growth (Loxton pers. comm.). Tipping does not decrease bruising (Wythes et al. 1979a). Mixing horned and hornless cattle increases the bruising of hornless animals (Shaw et al. 1976), yet mixed groups continue to predominate among consignments to saleyards and abattoirs throughout Australia (Eldridge and Hollier 1982; Wythes unpublished data). Industry seems reluctant to grapple with this problem by removing horns or penalizing horned cattle.

The expertise of stockmen and the design, construction and maintenance of yards affect greatly the ease of handling animals. It is important to build facilities that exploit fully the natural behaviour of livestock, particularly trucking, sale and abattoir yards where large numbers of animals are handled. Dodt et al. (1979) attributed a 54 percent reduction in bruising to alterations to both property and abattoir yards. Careful handling of cattle does not seem to be a major cause of bruising (Wythes et al. 1979b) or to affect muscle pH (Wythes and Underwood 1980). Rough handling should not be used. Familiarizing livestock with yards and handling procedures may reduce the probability of stress and bruising. Such training should begin at weaning. Attention to preparation of sale drafts by segregating animals according to size, sex, body condition and horns should minimize stress, bruising and deaths.

The physical stresses associated with transportation can have important effects on meat quality. Kilgour and de Langen (1970) demonstrated a physiological response by measuring a temporary rise in plasma cortisol levels of sheep on trucks. Tranquillisers have been used with some success in attempts to reduce stress (Ginsberg et al. 1963). Muscle glycogen concentrations decline during travel and insufficient rest can mean an increase in muscle pH values. Nevertheless, available evidence suggests that distance per se is not critical to pH values in cattle (Wythes et al. 1981) and pigs (Davies 1982). It is postulated that resting of animals during a long journey permits a partial or complete, though temporary, recovery of muscle glycogen concentrations before subsequent travel. However the effects of resting during transit on meat quality have not been studied. A number of studies would also indicate that the level of bruising in steers does not necessarily increase with distance travelled, though it may do so with cows (Yeh et al. 1978; Wythes et al. 1981). Certain metabolic disorders and diseases are associated with transport stress, for example, transport tetany. Disease-affected animals are detected by veterinarians during ante mortem inspections and rejected or slaughtered separately. It is feasible that some animals suffering from sub-clinical metabolic diseases (for example, ketosis) may be undetected and have high pH values. Certainly, "downer" dairy cows can have higher pH values than normal ones (Warnock et al. 1978).
Resting animals before slaughter allows them to recover from the journey, adapt to the surroundings and replenish muscle glycogen concentrations. Rest usually reduces pH values in sheep and beef carcasses (Shorthose 1977; Shorthose et al. 1972; Wythes et al. 1981). While rest also can be beneficial to pigs under some circumstances, there are reports of increases in the incidence of high pH values with increasing time in lairage (Moss and Robb 1978; Davies 1982). This also applies to calves (Butcher 1975). High pH values can occur, if animals do not rest adequately because of noise, abattoir activities and other disturbances. For example, mixing strange groups of animals upsets the established social order resulting usually in high pH values, particularly among bulls (Moreton 1976; Grandin 1979). Feasting alone at abattoirs does not appear to be detrimental to meat quality of cattle (Howard and Lawrie 1986), except possibly after more than three days (Wythes and Underwood 1980). However, feeding is not always beneficial to sheep and cattle (Shorthose 1977; Shorthose et al. 1972). Combinations of stresses, such as feed deprivation and excessive exercise, can increase the incidence of dark cutting in beef (Howard and Lawrie 1956). Fortunately, well-fed animals can usually withstand stresses better than fasted animals.

The total time from farm to slaughter may be prolonged by insufficient planning before and during marketing, excessive travel and unforeseen events. Despite the confounding of time and distance, increases in the total time affect meat quality adversely (Shorthose 1980). He also reported a greater incidence of high pH values in cattle from saleyards than those sent direct to the abattoir, as did Butcher (1975) for calves.

Handling and transport practices affect the degree of bacterial contamination of hides, fleeces and skins, through faecal contamination of animals on the lower decks by animals on higher decks in transports, and overcrowding in dirty or muddy holding yards. The bacterial load on the hide influences the numbers of bacteria that are transferred to the carcass during dressing procedures and therefore the keeping quality of meat. Handling practices also influence contamination of the carcass with salmonellae. The longer animals are held before slaughter, the greater their chance of being infected with salmonellae, especially if fed intermittently (Brownlie and Grau 1967).

Adverse weather conditions have a harmful effect on muscle pH and marked seasonal fluctuations can occur. Furnival et al. (1977) showed that cold overnight temperatures can increase the ultimate pH of lambs mustered 24 h before slaughter, while Shorthose (1980) found the same effect with feedlot steers. Pigs are especially susceptible, with increasing daytime temperatures causing an increase in mortalities (Allen et al. 1974).

Any depletion of muscle glycogen concentrations immediately before slaughter is detrimental, because animals do not have time to recover. Every attempt should be made to avoid exhaustion, excitement, struggling, undue or intermittent loud noises and rough handling. Shorthose (1980) reported that order of kill was important, since 5% of the first animals killed had high pH values compared with 25% of the last ones. Poorly designed knocking boxes can cause bruising at abattoirs (Meischke and Horder 1976). The severity of bruising increases with time between stunning and 'sticking', as the blood pressure approaches zero only after bleeding.

With careful attention to handling and transport, producers should be able to sell the maximum weight of bruise-free, tender meat. On the other hand, if animals suffer severe hardship, fewer may survive and they will yield lighter, bruised carcasses with tough meat. However even with good husbandry, it is
impossible to alleviate all stress and bruising, because of the variation in susceptibility between animals and continual social interaction within any group. Some stress and bruising are inevitable during transportation. Despite this, prudent attention to welfare will bring its financial rewards, but the converse, the neglect of livestock is immediately costly and could have serious long-term repercussions for all livestock industries.

CATTLE HANDLING FACILITIES

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The substantial losses associated with the beef marketing systems were highlighted by a number of studies and surveys in the early 1970’s (Meischke 1975), and as a consequence, cattle handling techniques and facilities are being subjected to closer scrutiny. The increased on-farm handling associated with intensive production, and compulsory health procedures together with liveweight selling have led to a demand for facilities that reduce carcass damage during the marketing phase of meat production. This paper considers the design of handling facilities based on the inherent behavioural characteristics of cattle, and the impact that these designs have on the efficiency of movement. It is considered that such facilities may cause less injury and be less stressful to the cattle being handled.

BEHAVIOURAL CHARACTERISTICS

Intrinsic behavioural characteristics which are believed to be important for the design of handling facilities and the method of handling cattle are

(i) almost 360° panoramic vision and relatively narrow field of binocular vision,
(ii) following and herding,
(iii) noise perception and
(iv) sense of smell (Grandin 1980). This relatively narrow binocular field together with the ability to discriminate most colours causes them to baulk at shadows or bright spots, and be reluctant to move towards dark areas (Grandin 1980; Baker and Mayes 1977).
Consequently, designs that incorporate strong contrasts in light and shade or colour should be avoided. Examples of these are vertically slatted fencing and drainways crossing the path of stock.

Cattle have a strong herding and following instinct (Grandin 1980; Kilgour 1978a) and therefore groups of animals tend to move together. A single animal easily becomes frightened and is hard to move. Cattle are sensitive to noise, and may be panicked into unpredictable behaviour by loud noises. Unfamiliar smells, and the smell of blood at abattoirs may cause cattle to baulk, and to be difficult to handle (Grandin 1980). A good stockman is aware of these behavioural characteristics, and has an instinctive awareness of the flight distance of the cattle being handled. Cattle may be approached to the edge of a flight zone, and encroachment upon this zone causes cattle to move away from the handler (Grandin 1980). Flight distance around the animal depends on animal factors as well as the method of handling. The closer the animal can be approached, the more control the stockman has over them in handling situations.

DESIGN OF FACILITIES

Stocking densities of approximately 0.54 animals per square metre (animals weighing 450 kg live weight), have been suggested for holding areas (Johnson 1977, Anon. 1978). However there are no data available for stocking densities or trough space that are suitable for watering cattle as required by the various codes of

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practices for the liveweight selling of cattle. Kilgour (1978b) suggests that pen shape may be important in reducing interaction between individuals in holding pens. It is believed that long narrow pens may achieve this as cattle prefer to rest near fences, and this pen shape has a high fence to pen area ratio (Grandin 1980). While rectangular holding pens, may be more suitable for unfamiliar lots of cattle at abattoirs, selling pens at saleyards need to be built on a square grid basis to enable fair presentation of stock, and minimize costs. However, for all square or rectangular yard situations, it is important to design laneways, yard orientation and gate angles in such a way that the cattle are turned through less than 90°. Where cattle are to be sorted on farms, in liveweight selling facilities and abattoirs, circular yards should be used where possible as they contain the largest area per metre of external fence, have no corners to disrupt movement, and utilize the natural trait of cattle to circle the operator (Vowles 1980, Grandin 1980).

Fences should present a visual barrier to cattle and a wide breast rail ensures that cattle can see an obstacle when being worked (Vowles 1976, Grandin 1980). Solid fencing should be used if external distractions are likely to disrupt the flow of cattle, although in some situations, solid fencing may cause baulking. Contrary to the beliefs of Rider et al. (1974) and Grandin (1980) who recommend totally enclosed forcing areas, it has been my experience that for most on-farm situations in Victoria, open or only semi-solid fencing may be beneficial, as cattle appear to be less hesitant to enter these areas, perhaps because they feel that they are not being moved into a restricted area which is smaller than their flight zone.

Yard designs now being recommended in Victoria (Vowles 1980) have curved races that should be fully clad on the outside and to a height of only 900 mm, on the inside. This allows the operator positioned on the inside of the curve to fully utilize the principles of flight zone and correct approach angles. A recent comparison of efficiency of cattle movement between yards employing these principles, and yards of the more traditional design with a straight race and single gate triangular forcing yard, on a number of properties in Victoria indicated that handling time could be almost halved from an average time of 9.8 seconds per animal through the traditional facilities to 5.8 seconds per animal through the new design (Vowles and Hollier 1982). In addition to this improvement in efficiency a correctly designed curved and tapered race can be used for batch treatment of animals. This procedure is much more efficient as stock are less confused, and spend less overall time in the race area compared with single animal treatment in a crush. Cattle baulk at overhead frames, walkways, and antibacking devices in races; however, their following behaviour can be utilized by using sliding gates and pen divisions of open material.

There appears to be general agreement on design requirements of cattle loading ramps. Single animal races 750 mm wide are ideal for loading, whereas full truck width is the optimum for unloading (Anon. 1977). Cattle prefer to walk up steps rather than inclines (Kilgour 1978a) the suggested dimensions being 460 mm length for each 100 mm rise (Mayes 1978; Vowles 1981). A level section at truck height, a curved approach and totally enclosed sides are also aids to movement (Vowles 1976; Johnson 1977; Wythes 1981).

Facilities designed for optimum stock movement are generally less stressful to stock, and safer for handlers. However, it should be recognised that the manner in which the stock are handled probably has a greater influence on efficiency of movement, and stress and welfare than does design. There is no substitute for quiet handling, and common sense when handling stock.
Sheep are handled at least twice a year, for shearing and crutching, and the majority are handled more often. The handling process involves mustering, movement through yards, sheds, or races, and finally, administration of a treatment. Sheep movement is usually prompted by the use of fear evoking stimuli and the treatment is usually aversive. Bruising or physical injury can result from human cruelty when sheep baulk or refuse to move.

Thus, sheep handling involves three aspects which are directly concerned with both efficiency and welfare. These are (i) the design of the handling environments and facilities, (ii) the handling technique which is used, and (iii) the treatment which is administered to the animal.

**DESIGN**

The basis for the design of sheep handling facilities in the past has been utility, but recently more efficient facilities have been designed around responses of sheep. At Melbourne University we have investigated the responses of sheep to many aspects of the physical environment (e.g. corners, inclines, light intensity, shed floors, and wind) and also the social environment (e.g. the sight, sound and smell of other sheep) and we have made many recommendations about environmental design which will improve the flow of sheep through yards, sheds and races (Hutson 1980a). These improvements will have a direct effect on welfare through smoother flow of animals and less need to force animals with fearful stimuli. This should also reduce frustration in the handler and result in less abuse of the animals.

Two aspects of sheep behaviour have important implications for facility design. The first is that the sheep has excellent, wide angle vision (about 270° in Merinos), and keen depth perception (Walk and Gibson 1961; Clarke and Whitteridge 1973; Hutson 1980b). Thus, in designing handling facilities it is most important that sheep have a clear, unobstructed view of the exit, or towards where they are meant to move and that discontinuities in flooring such as shadows, grates or longitudinal slats are avoided. The second aspect is that sheep readily learn a handling routine and will remember it indefinitely. It is therefore critical that sheep are moved through yards, sheds and races in the same direction and along the same route for each handling procedure (Hutson 1980c).

**HANDLING TECHNIQUE**

The traditional motivation used to move sheep is the repeated application of fearful stimuli. Sheep handlers use dogs, the natural predators of sheep, or auditory and visual signals, such as shouting and waving, to frighten sheep to move (Baskin 1974). However, alternative motivations such as utilization of the flocking — following instinct or use of positive reinforcements could be just as efficient and less stressful to the sheep. Bremner et al. (1980) have successfully trained Judas sheep to lead other sheep to slaughter and Hutson (1982) has reported that sheep rewarded with barley after handling moved more freely through a race system than unrewarded sheep.

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Stockmanship appears to be a skill acquired by experience, although it is tempting to speculate that it could also have an innate basis. Good stockmen make the minimum possible use of fearful stimuli, avoid punishing animals, and use positive reinforcements. They have an understanding of animal psychology which is probably based on acute powers of observation (Ewbank 1968). For example, good stockmen avoid loud noises as sheep will associate noise with the handling procedure; act quickly and decisively because if handling is fumbled animals become more difficult to restrain (Ewbank 1968); have an awareness of the flight distance of sheep and know that alarm can be communicated to other animals; know that it is easier to fill a race when there is room for a number of animals rather than fill it one animal at a time (Grandin 1980). Much of this knowledge is common sense, but more research is needed to make the techniques of good stockmanship more explicit for inexperienced handlers.

THE TREATMENT

Although design and technique are very important in handling facilities, the main problem with obtaining an efficient throughput appears to be the nature of the treatment inflicted on the sheep. During an evaluation of a race system we found that race efficiency dropped from 93% to 73% after sheep had experienced inversion for 30 sec in a handling machine (Hutson and Butler 1978). This indicates that many routine treatments are aversive to sheep and that they may function as negative reinforcers of the behaviour we are trying to encourage – moving freely through a race system.

There has been some research done on the nature of the treatments performed on sheep and whether they are stressful. Kilgour and de Langen (1970) measured plasma cortisol levels in sheep for different treatments. They found a great deal of individual variation, but some treatments appeared to stress sheep more than others. Dog chasing (especially when bitten) and prolonged shearing produced the highest cortisol levels. The most stressful part of any treatment performed on sheep appears to be isolation from the mob. Syme and Elphick (1982) have measured heart rates in sheep as a prelude to introducing standard stressors, such as prods, in order to get them to move. Again, they found wide variation between individual sheep but the simple procedure of isolation of a sheep from the flock to measure heart rate masked any additional effects caused by the stressors.

The main management operations carried out with sheep range from minor treatments such as drafting or drenching to major treatments and mutilations such as shearing and mulesing. The problem is to perform these treatments on sheep with the minimum use of fear inducing stimuli and to reduce the negative reinforcing effects of the treatment itself so that sheep will move freely through the handling system on subsequent occasions. There are probably several solutions to this problem.

1. Reduce the severity of the treatment. This seems to be very difficult to achieve, unless anaesthetics, acupuncture or hypnosis techniques can be used. However, treating sheep in groups could be a method of minimising isolation induced stress.

2. Intersperse the major treatments or mutilations with less severe handling procedures such as drafting or classing.
3. Counteract the negative reinforcement with a positive reinforcement immediately after handling. In some preliminary experiments I have found that rewarding sheep with barley after handling reduced the amount of labour required to push them up along a race (Hutson 1982). It might therefore be possible to condition sheep at an early age to associate food rewards with handling and so improve their ease of handling over a lifetime.

**PIG HANDLING FACILITIES**

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Pig handling facilities fall into two categories. First, there are the intensive housing facilities and second, as for cattle and sheep, an occasional handling facility is required for weighing or loading onto transport. As pigs have poorly developed eyesight and can be difficult to move through unfamiliar areas attention to design will improve movement, avoid acute stress and reduce the incidence of stress related problems in meat characteristics (Hails 1978). However, the consequences of the various housing techniques of pigs are uncertain in terms of welfare (Wood-Gush et al. 1975) and meat quality. This paper describes three aspects of pig handling facilities that may cause problems: the physical environment, man-animal interactions and barriers to movement within piggeries and during transport.

**THE PHYSICAL ENVIRONMENT**

Pigs are housed under a variety of intensive and extensive conditions in Australia, with the major variable being space allowance: this is adjusted by varying pen size, group size and the use of tethers. The major question in relation to intensive housing is its effect on welfare status, and to interpret the literature, in relation to welfare we can examine four areas: while there is a general consensus that behaviour, injuries and stress physiology can be used to assess welfare status, the opinions over production criteria are equivocal. As stress has an effect on nitrogen balance with consequent effects on muscle growth (Imms 1967), a poor growth rate in animals on an adequate diet can indicate the existence of a chronic stress response.

(i) **Penning** The influence of group size and density on behaviour and productivity of growing pigs has been comprehensively reviewed (Syme and Syme 1979). Growing pigs housed with less than 0.6 m² per pig have a reduced growth rate, and higher stocking density appears to be associated with increased aggression. If group size exceeds 10 or 12 there may be lower growth rates but the influence of group size on adult pigs is not clear. Visual and tactile isolation of pigs is associated with a chronic stress response as evidenced by higher free plasma corticosteroid levels compared to pigs in groups of three (1.5 m²/pig) (Barnett et al. 1981). In a survey of breeding sows that were housed during gestation either in crates or in groups with access to a paddock Bäckström (1973) found increased agalactia, farrowing time, sow morbidity at farrowing and a higher incidence of stillborn piglets in the restricted sows. Although group housing may provide the best environment for pigs from a welfare point of view, both the optimum group and pen size remain unknown. In a current study comparing five housing treatments for sows we found no significant differences in free corticosteroid concentrations in pigs housed either indoors (in tethers or groups of five) or outdoors (in groups of six, either on concrete or in a paddock). However, pigs housed indoors in pairs had significantly higher

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free corticosteroid levels than all other treatments indicating a chronic stress response; this may have been due to this treatment having the greatest social restriction, or the increased retaliation which occurs in small groups (Bryant and Ewbank 1972). Rampacek et al. (1980) also found no significant differences in corticosteroid levels between pigs in groups housed either indoors on concrete or outdoors on a paddock. However, in both these studies, pigs housed indoors in groups had the lowest corticosteroid levels ($P > 0.05$). The pigs in these studies were reared indoors in groups on concrete and therefore rearing experience may be an important variable in subsequent responses to housing treatments.

(ii) Flooring. Floors have to be both durable and comfortable for pigs to rest and walk on. A study of the behaviour of sows and piglets on three types of farrowing house floor (concrete, epoxy-painted concrete and rubber mats) showed that rubber mats best fulfilled the behavioural needs of the sow and of the piglets. However, the size and severity of knee injuries of the piglets were greater on rubber mats (Gravas 1979). Other studies with fattening pigs have indicated that solid concrete and broad slats are more satisfactory for walking on than narrow slats, and that partially slatted floors are generally preferable to totally slatted floors (Steiger et al. 1979). The incidence of foot lesions in sows is greater on slatted than non-slatted floors (Ekesbo 1980). The addition of straw to partially slatted floors improves the 'well-being' of fattening pigs (Van Putten 1980); it provides a material that occupies pigs for 1.5 h per day and there is a reduction in tail-biting, nibbling other pigs and nibbling inanimate objects.

The requirements for floors may conflict; Jackson (1976) probably summed up the situation well when he stated "the ideal floor for pigs does not exist".

Considerable work is required in the whole area of optimum housing conditions.

MAN-ANIMAL INTERACTIONS

In a recent study on livestock behaviour and handling facilities Grandin (1980) commented that pigs are 'social and sensitive by nature and respond to gentle and considerate handling'. Data we have obtained provide empirical production, behavioural and physiological evidence for this comment. Hemsworth et al. (1981a) showed that in 12 similar one-man piggeries in Holland, the number of piglets produced/sow/year was greater at the farms in which sows displayed greater approach behaviour towards a stationary human and a lower withdrawal response to an approaching human. To quantify some of these relationships, at Werribee pigs were reared from 11 - 22 weeks of age in either a 'pleasant' or 'unpleasant' manner. Unpleasantly handled pigs showed evidence of a chronic stress response in the absence of humans, an acute stress response in the presence of humans, a lower growth rate (5%) and poorer feed conversion rate (6%) than pleasantly handled pigs (Hemsworth et al. 1981b).

Therefore, a good man-animal relationship can lead to both increased productivity and an improved welfare status.

BARRIERS TO MOVEMENT

After fattening, pigs have to be moved to slaughter. At this time they are expected to withstand a variety of stressors. For example, moving pigs into a new pen is associated with an acute stress response which is greater when social interactions (among strange pigs) are involved (Barnett, unpublished). This response disappears within 24 - 48 h. Problems in moving pigs have been reviewed by Van Putten and Elshof (1978) and Grandin (1980). Steep slopes, narrowing
passages and sharp turns, shadows and dark areas, electric prodders and mixing strange pigs should be avoided.

Animals have the ability to respond to stress but the limits within which this can occur without affecting welfare and meat quality are largely undetermined.

THE TRANSPORT OF LIVESTOCK

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The stressors to which animals may be subjected during road and rail transport from farm to slaughter include noise, movement, change in social and microbiological environments, deprivation of food and water, loading and unloading, strange smells and toxic exhaust wastes from the transport vehicle (Hails 1978; Pearson and Kilgour 1980). A single stressor may have little effect on the animal, however combinations of these stressors can lead to major changes in behaviour and physiology, affect carcass quality and if severe enough, can lead to death. This paper considers the effects of management and design of equipment for transport from farm to abattoir, on the welfare and meat quality of livestock.

MANAGEMENT AND OPERATION

Decisions on modes and conditions of transport of animals from farm to sale or slaughter is based on the availability of alternative means of transport and on the minimization of direct costs to the producer. Although rail transport is relatively slow and often involves many stops and the unloading and reloading of animals, it is usually chosen for long distances as it is less expensive than road transport (Daly 1978). On the other hand, road transport is almost exclusively used over short distances. In most cases of road transport, stock are carried directly to their destination without unloading, although Davies (1982) found that about 20 percent of pigs carried by road in Victoria were unloaded and reloaded at collection points enroute to the abattoir. Eldridge (unpublished data) also observed that small lots of cattle are commonly transported in this way.

Attempts to relate adverse effects of transport to length of journey have been unsuccessful, probably because there are so many factors which act and interact to influence the level of stress experienced by the animals during transport. Extending the length of the journey was found to have no effect on the ultimate pH in cattle (Wythes 1981; Yeh et al. 1978) or in pigs (Cuthbertson and Pomeroy 1970; Davies 1982), although it did increase the ultimate pH in sheep (Shorthose 1977). However, from the many reports on the effects of high temperature (Hails 1978), extending the length of journey is likely to be much more stressful in hot than in mild weather. The effects of transport on meat quality can also depend on the management of stock before and after transport. Dodt et al. (1979) reported that fasting prior to transport increased the level of bruising in cattle while Cuthbertson and Pomeroy (1970) found that decreasing the time spent by pigs in lairage after a short journey could lead to an increase in the incidence of pale, soft and exudative (PSE) meat.

On long journeys, which can exceed 1000 km and take many days, stock are often unloaded and loaded many times before they finally reach their destination. There is no experimental data on the length and interval of rest periods in transit and consequently rest periods are usually based on transport regulations, costs and perceptions of animal welfare. The Victorian Codes of Practice

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(Anon. 1981a) recommends that ruminants should be rested and offered food and water at least every 36 h. However there is evidence to suggest that the stress of unloading and loading may override the benefits unless the rest period is at least 15 to 24 h and encompasses the normal grazing times (Kilgour and Mullord 1973; Ewbank 1975; Hails 1978). Davies (1982) found that when pigs were unloaded and reloaded at collection points during transport to slaughter, that there was an increase in the ultimate muscle pH indicating that these procedures had indeed been stressful.

Correct loading density is important and the Victorian Code of Practice for the Transport of Livestock (Anon. 1981a) emphasizes that trucks should not be loaded either too loosely or tightly as both predispose stock to injury. However, there is no scientific information concerning the influence of loading density on animal welfare, so that in drafting the code of practice for rail transport of livestock, the Animal Welfare - Rail Transport Group of the South Australian Department of Agriculture made recommendations for loading densities based on information gathered from experienced livestock handlers. The recommended densities were 0.70, 1.25 and 1.70 animals per square meter for adult and yearling cattle and calves, 3.3 and 4.0 for adult sheep and prime lambs and 3.3 and 4.0 for baconers and porker pigs respectively. Similar densities have been recommended for pigs on road transport (Melrose 1979) and for rail transport of cattle in Queensland (Anon.1981b). Eldridge (1982) found similar loading densities for cattle trucked in Victoria, however there appeared to be little consideration given to the size and shape of the animal as there was a tendency for heavier cattle to be packed more tightly than smaller ones of the same class.

Mixing unfamiliar groups within the same pen will cause restlessness and antagonism (Pearson and Kilgour 1980). Injuries associated with transport have been shown to constitute up to 8.5 percent of total loss of meat in pigs and on one survey 40 percent of all pigs inspected were damaged by fighting (Hails 1978). However, Wythes et al. (1979) and Yeh et al. (1978) reported that mixing of unfamiliar cattle, had no effect on the level of bruising and muscle pH, even when this involved mixing cows with steers. The number of stops during transport should be kept to a minimum as it is generally reported by transport operators that stock become restless during stops, there is an increase in the level of bruising in cattle with the number of stops (Ramsay et al. 1976) and that the incidence of fighting increases with pigs while the vehicle is stationary (Pearson and Kilgour 1980).

TRANSPORT DESIGN

Until recently there has been little critical examination of the design and construction of livestock vehicles. Most rail trucks were designed over 30 years ago and only slight mechanical modifications have been made to cope with higher speeds. Crates for road transport of animals have a shorter life span than rail and more modern designs have evolved from the experience of truck operators and improvements in fabrication and suspension design. Guidelines for construction of truck stock-crates have now been produced by the National Materials Handling Bureau (Anon.1977) and the Standards Association of New Zealand (NZS 5413:1977), but these give no detailed advice.

The pen area and number of pen divisions on cattle trucks are extremely important for animal welfare and safety, particularly in emergency situations. Nevertheless, it was found that pen area on these vehicles in Victoria was extremely variable (Eldridge 1982). When fully loaded and packed to a density which will prevent excess movement of animals within pens, most livestock vehicles exceed the gross weight permitted by national road regulations and in some cases may even exceed that recommended by the manufacturers of the transport equipment.
Consequently, specifications for livestock crates should consider total deck area, loading density and live weight of the stock, suspension and the carrying capacity of the vehicle.

Problems associated with bruising during transport can be largely overcome by good vehicle maintenance, careful handling of stock during loading and unloading and improved driving techniques. However at present there is insufficient data available on which to base any radical changes or improvements in design or construction to overcome problems associated with stress and welfare during road transport. Work is currently being undertaken in Victoria to study the effect of pen size and loading density on the level of stress and other factors that may effect animal welfare and safety during road transport. Some work has already been carried out in Queensland on the effect of roofing rail wagons on internal temperature in order to reduce heat stress of animals during rail travel (Anon 1981b). Attention to improving management of stock on the farm, at the saleyards and abattoirs will help reduce the effects of transport stress on meat quality and may help reduce the risk of injury. Nevertheless, considerable work is required if the meat producer and transport operator are to meet the requirements of the community for animal welfare during transportation and reduce still further losses due to injury and poor carcass quality.

CONCLUSION

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Incompetent handling of livestock and poor transport techniques results in reduced carcass yield and quality. The cost of bruising in cattle was estimated to be $26 million in the early 1970's (Meischke 1975) and although the cost of bruising in sheep has not been quantified in Australia, Thornton and Gracey (1974) suggested that it was too great to be ignored. No attempt has been made to cost the loss of pig meat due to bruising or to estimate the cost of down grading or condemning carcasses due to stress factors such as dark cutting of beef and sheep meats and PSE and DFD meats in pigs. Because of the difficulty of determining where and when bruising or stress occur in the meat harvesting process these costs are absorbed into abattoir operating costs, passed onto the consumer or debited against the producer through average dressing percentages.

Careful handling, stockmanship and stockmanagement together with good design and maintenance of handling and transport facilities in all parts of the harvesting chain will significantly reduce the level of bruising and improve meat quality. A continued research effort is still required to isolate and solve problems and improve handling and transport of slaughter animals particularly in relation to stress and welfare. The design of animal facilities based on ethological and physiological data should go a long way to alleviating stress during handling situations and perhaps reduce the level of bruising still further.

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