RESLAUGHTER HANDLING, STUNNING AND SLAUGHTER

G. GREGORY

partment of Meat Animal Science, University of Bristol, Langford, Bristol BS18 7DY, United Kingdom

MMARY: This paper reviews some of the recent developments in scientific research into preslaughter handling, transport, stunning and aughter. Particular emphasis has been placed on work published within the past two years, and on the welfare and meat quality aspects of subject.

ELFARE AND PRESLAUGHTER HANDLING: In recent years a lot of new legislation has been put forward within Europe on slaughter handling, transport, stunning and slaughter. Some of it has been based on science and other parts on practical experience plus uition. Science has been particularly useful in the case of stunning and slaughter, but livestock transport has been a more difficult subject legislate for on the basis of scientific evidence alone. This is because of the greater variation in circumstances and the more nebulous ture of the perceived welfare problems. There are in fact eight ways in which preslaughter handling can compromise animal welfare able 1).

ble 1. Welfare problems associated with transport of livestock

Death	Metabolic exhaustion
Bruising	Dehydration
Broken bones	Emotional stress
Torn skin	Temperature stress

ysiological investigations based on liver glycogen depletion during fasting or transport have defined the periods over which metabolic haustion will occur. For example in pigs the fasting interval over which liver glycogen is depleted to less than 10% of its normal value in fed state is 21h (Warriss and Bevis, 1987), and on this basis it has been recommended that journeys should not exceed this interval thout a feeding and rest period. In the case of sheep and broiler chickens the respective values are approximately 24 and 6 h (Warriss *et al*, 87; 1988). In the future similar research should be performed on the time to onset of physiological dehydration, and perhaps into the ersive effects of transport. In the meantime formulating legislation on the basis of metabolic exhaustion would be a useful achievement in elf.

ath: Death during transportation is more common in poultry and pigs than in the ruminant species but there are instances where it is portant in sheep. Warriss *et al* (1992) found in a survey of 1113 journeys involving 3.2 million broilers, that the longer the journey time higher the incidence of deaths. When journeys lasted less than 4 hours the incidence of dead on arrival (DOA) birds at the processing ants was 0.156%; for longer journeys the incidence was 0.283%. The relationship between deaths and journey duration is not linear, but stead it accelerates with time. This feature is probably common to other species, and it implies that either the conditions on board the hicle, and/or the condition of the animals, deteriorate as the journey progresses. In another survey, in which the DOA rate in broilers was 9%, it was found that 47% of the birds had died from congestive heart failure, and 35% of these birds had ascites. 35% of the total deaths re due to trauma (Gregory and Austin, 1992). Mortality is usually greatest during hot weather, and there have been reports of 50% rtality in end of lay hens being transported from Spain to the Netherlands. An obvious innovation which should help to reduce such sses would be the installation of temperature monitoring systems within the livestock compartment. These would include a display of the

temperature on the dashboard of the driver's cab and an audio warning system which informs him when the temperature goes outside limits. The driver then adjusts ventilation hatches remotely to regulate the temperature to the required level.

It is unusual for sheep and cattle to die during transport to an abattoir. For example the mortality rate recorded at one abattoir in the about 0.01% (T. G. Knowles, personal communication). However the situation is more grave in long distance transportation. Between 1 and 2.5% of the 7 million sheep exported from Australia to the Middle East die on the voyage, and this level can be as high Goats are even more susceptible; 8% died on the same route as the sheep, and the highest mortality for a single voyage was 16% 1991). There has been some excellent research into the causes of shipping mortality in sheep. Not surprisingly it is directly re journey duration, which in turn is influenced by the price of oil. When oil prices are high the master of the ship sets a low speed to c fuel and thus the journey lasts longer and mortality is higher. The time taken to unload the ship at the Middle East ports can also be c there is often little natural ventilation on the stationary ships which can hold over 50,000 animals. Unloading rate depends on whe sheep are off-loaded onto lorries (e.g. 800 sheep per hour) or into quayside feedlots (e.g. 3000 sheep per hour). The three main c death during the journey are inanition (47%), salmonellosis (27%) and trauma (12%). Inanition starts at the feedlot before embarkat the sheep are introduced to a pelleted ration. It is most common in those sheep which would tend to have a poor appetite anyway adult wethers (Higgs et al, 1991). In addition, there is a distinct seasonal pattern. In May the sheep come off dry pasture metabolism is atuned to fat mobilization. This persists during the journey and mortality amongst the inappetant sheep is low Whereas during August the sheep come of good pasture and have entered a phase of liveweight gain; there is a transient period of lo the inappetant sheep at the start of the voyage but this does not persist and mortality is higher even though they have ample body fa (3.3%; Richards et al, 1991). In sheep shipped from New Zealand inanition can be associated with a non-inflammatory diarrhoea due to a disorder in sodium metabolism and can be corrected to some extent by periodically including 10% sea water in the drinki (Black, 1990). In Australian sheep an inflammatory diarrhoea due to salmonellosis is more common, and this is usually seco inanition. Death from trauma occurs at loading onto the ship or during the first few days afterwards, but it is less common where floors are used.

Bruising, broken bones and torn skin: Bruising and broken bones are usually acquired when the animals are handled, and h the problems tend to be greatest in poultry. For example, the prevalence of broken bones when end of lay hens reach the waterbath the processing plant is 29% (Gregory & Wilkins, 1989). Much of this damage is in the ventro-caudal protruberance of the keel an margin of the ischium, i.e. those parts of the body which protrude and are unprotected when a bird is pulled backwards out of a c corresponding value for broilers is 3% in the live birds (Gregory & Wilkins, 1990), but in those that die during transport 27% had b or broken femurs (Gregory & Austin, 1992). Wing bruising is a common problem in turkeys and torn skin can be serious in duc are prone to climbing on top of one another when they are being caught.

Bruising tends to be less serious in pigs, but about 0.3% of pig carcasses in the UK are partly condemned for this reason (MLC, 19 way in which they gain bruises is from falling over as they are loaded or unloaded on the transporter. Warriss et al (1991) have re the importance of ramp angle in determining the ease and rate of moving pigs. Ramp angles up to 20° appeared to present few pr pigs regardless of whether they were ascending or descending. Above 20° there was a progressive increase in loading and unloa and from a subjective point of view slopes of 30° or more were particularly difficult to descend. Although slope is important it sho considered separately from cleat (foot support) spacing across the tailboard. When a narrow (15 cm) cleat spacing was used pigs

ope of 35° almost as well as one of 20°, but at a wide (30 cm) spacing they took almost twice as long. This has implications for vehicles ich are used for both cattle and pigs.

tabolic Exhaustion and Dehydration: It is common knowledge that stress before slaughter results in muscle glycogen depletion and k firm dry meat which can be more tender when cooked. This is a manifestation of metabolic exhaustion, and as such is sometimes used welfare parameter. It is also held that acute stress before slaughter can help to precipitate PSE meat by raising body temperature and moting a metabolic acidosis immediately before slaughter. This is most noticeable in Stress Sensitive (acidosis prone) genotypes. In e situations, however, PSE meat can be induced in both Stress Sensitive (SS) and Stress Resistant (SR) genotypes by the act of slaughter lf, particularly when there are violent convulsions such as those following captive bolt stunning (Klingbiel & Naude, 1977). Ahn et al 92) recently found that inducing a metabolic alkalosis with oral sodium bicarbonate prior to slaughter could help reduce the rate of pH fall he *l. dorsi* of captive bolt stunned pigs. This, however, was not necessarily due to a direct counteraction of the presence of acidity by arbonate ions, as the rate of post mortem muscle ATP breakdown was also reduced. It would be interesting to see whether an alkalosis uced preslaughter could prevent PSE meat production in SS pigs which are electrically stunned.

riss et al (1990) observed that holding pigs in lairage for 21 h instead of 2 h resulted in a decrease in the prevalence of potentially DFD k to 6% instead of 29%. Hitherto, longer lairaging has usually been associated with an increase in the expression of DFD. The difference his occasion was that the pigs had been fed in lairage the evening before slaughter and this provided a period for muscle glycogen letion. Feeding sugar in the lairage also helps to prevent muscle glycogen depletion, even when unfamiliar pigs are mixed in the same pen rnandez et al, 1992). When pigs are not fed or given sucrose in lairage Eikelenboom et al (1991) have recommended that the preslaughter ting period should be 16 to 24 h in order to minimise the prevalence of PSE meat, but 24 h fasting would be associated with more DFD.

eneral lamb meat quality tends to be less prone to the effects of metabolic exhaustion than pork or beef. For example it is unusual to hear ut high pH_u dark lamb commercially. Nevertheless there are some instances where antemortem stress has caused a high pH_u and has led more tender meat when it has been cooked. For example chasing lambs on horseback has resulted in high pH_u tender meat. By contrast ronic stress induced by electric shock treatment repeated over a long period of the animals' lives has resulted in tougher lamb meat. Aalhus al (1991 b) have just reported that chronic treadmill exercise had a tenderising effect, and they suggested that this could be due to a reduced el of collagen in relation to myofibrillar protein content rather than a high pH_u phenomenon. Bray et al (1989) examined the effects of earing, underfeeding and washing before slaughter on subsequent meat quality in 10 month old lambs. Shearing and underfeeding did not ve much effect, but washing and combinations of two or more of these treatments resulted in a raised prevalence of high pH_u meat. These ects, however, were not big enough to influence meat tenderness or colour.

hydration is a surprisingly underresearched subject. It is well recognised that dehydration makes skin removal difficult in sheep, and it oduces a sticky textured meat. Little is known about other organoleptic properties of meat from dehydrated animals and even less is known ut the prevalence of dehydration as a welfare problem.

notional and temperature stress: Transportation is a novel situation for most slaughter stock and as such it produces apprehension if stress. However, practical experience tells us that repeated transportation of the same animal does not appear to be aversive, otherwise it uld become progressively more difficult to load them onto a transporter with each successive journey. This implies (but evidence is quired to prove the case) that transportation is not necessarily an intrinsically emotionally stressful experience. This generalisation, wever, requires some qualification, as no doubt it does not apply to all journeys.

A striking feature in modern livestock transporters is the noise they create. The livestock compartments used to be made of wood and [illegible] but now they are usually all metal. As a result the noise within the livestock compartment of sheep and pig transporters often exceeds [illegible] decibels (T. G. Knowles, personal communication). It should be remembered that 93 decibels is a serious hazard to human hearing [illegible] experienced for more than 4 hours.

HYGIENE AND PRESLAUGHTER HANDLING: Preslaughter handling can also have a bearing on the hygienic quality [illegible] carcass. For example, holding animals in vehicles or lairages without adequate litter and/or drainage can result in faecal soiling of [illegible] In addition, fasting cattle prior to slaughter results in an increase in rumen pH which can favour the survival of salmonellae, and if the [illegible] are fed during lairage these microbes can multiply rapidly. The importance of these effects will depend on the likelihood of contamination [illegible] the edible carcass with gut contents, and this in turn depends on a large number of other practices within the plant.

In the future greater emphasis will be placed on the effects of preslaughter handling on faecal contamination of the animal's body [illegible] lambs are commonly recognised as a problem by processors when the pelt rolls onto the edible carcass. Official Veterinary Surgeons [illegible] likely to object to dirty pigs entering the killing line, and there are three ways to approach this problem. Either greater effort should be [illegible] in ensuring that pigs are provided with adequate clean bedding at the farm, during transport and in lairage, or the pigs should be washed [illegible] the lairage, or the carcasses should be scrubbed and washed before entering the scald tank. Shavings are sometimes a more [illegible] proposition than straw for transporters and lairages, because they are less prone to blocking drains. It is interesting to note however that holding pigs on shavings containing wood preservatives can lead to the rapid (within 60h) incorporation of pentachlorophenol in liver [illegible] & Frank, 1991). Whether this is sufficient to produce a taint is not known. Cleaning pigs with a shower in the lairage is probably the [illegible] effective of the three alternatives. However, Long & Tarrant (1990) reported that showering in cold weather can reduce the drip [illegible] meat, probably because it resulted in more rapid carcass cooling thus reducing the expression of PSE characteristics.

STUNNING AND SLAUGHTER

Electrical stunning: Most of us are familiar with Hoenderken's work (1978) which demonstrated that the current which would [illegible] epileptiform activity in the electrocorticogram (ECoG) in 98% of his pigs was 1.3 Amp. This has now been used in the Proposal for [illegible] Regulation on the protection of animals at the time of slaughter or killing. Based on experience in man it was assumed that the [illegible] of epileptiform activity was indicative of unconsciousness and that this was a suitable criterion for effective electrical stunning.

Since Hoenderken's work, Anil (1991) has shown that on average 150V (0.41 Amp) applied for 3 sec resulted in the absence of any [illegible] response to a nose prick for 57 sec. At its shortest this reflex was absent for only 38 sec. It appears, therefore, that Hoenderken's [illegible] work, which were based on completely different criteria, have produced two uncomplementary recommendations. It must be [illegible] that Hoenderken's work examined the current applied across the neck that was sufficient to induce an adequate stun as determined [illegible] ECoG (1.3 Amp), whereas Anil examined the effect of tong application across the head on the induction and return of physical behaviour [illegible] was indicative of unconsciousness (0.41 Amp). The weakness of the former approach is that unconsciousness could be present in the [illegible] absence of an epileptiform ECoG. C.C. Daly (personal communication) for example has observed that overt behavioural unconsciousness [illegible] can be produced with electrical stunning in sheep without the production of epileptiform activity in the ECoG. Similarly, [illegible] Wotton (1989) observed in 17 chickens that were electrically stunned using a waterbath stunner, that 4 of them lost their somatosensory [illegible] evoked potentials but failed to develop polyspike activity in the electroencephalogram. These observations imply that electrical [illegible]

uce insensibility without producing epileptiform activity in the ECoG. Assessing unconsciousness from the physical behaviour of animals been criticised because it is impossible for animals to express reflex behaviour whilst they are in a tonic or convulsive state (Roos & opmans, 1934). This argument can be more clearly defined by asking whether the hypersynchronous discharges which provoke the vulsions originate in the brain? If they do not, then it is possible that the animal could be conscious. This however leads to a circular ument, because to resolve this one has to look for epileptiform activity in the ECoG. The conclusion that we draw from all this is that ommendations based on work which examined spontaneous or evoked activity in the ECoG provide an unequivocal assessment of onsciousness, and for the time being they are a more certain criterion than physical behaviour. However, the new evidence which gests that they may be overexacting criteria deserves further attention, as does the positioning of the stunning electrodes.

il & McKinstry (1992) have also reported that the time to recovery of conscious reflex activity in pigs following high frequency (1590 Hz) trical stunning is quicker than for a 50 Hz current. Here again consciousness was assessed in terms of the physical response to a nose k with a needle and the onset of head righting behaviour. The shorter recovery time with high frequency stunning occurred even though it associated with a slightly higher rms current.

widely recognised that inducing a cardiac arrest at stunning has two distinct welfare advantages. Firstly, since it results in a rapid loss of n function, it ensures that the animal will not regain consciousness after the stun. Secondly, it does not depend on the slaughterman forming an accurate stick in order to ensure that the animal does not regain consciousness. Head to back stunning which simultaneously ns and induces a cardiac arrest was originally developed in Germany and the UK in the late 1920s. However, it was not until the 1980s it was used commercially in sheep in New Zealand. Some sheep plants have now started using it within Europe, and several pig ughterhouses have tried it but only for a short period because of problems with broken vertebrae. Grandin (1986) observed that longer rent application times were associated with a higher prevalence of broken backs. Wotton et al (in press) have recently reported that the valence of broken vertebrae also depends on the position of the rear electrode. When that electrode was placed in the region of the fourth seventh cervical vertebrae there were no breaks, but only 63% of the pigs had a cardiac arrest (with 1.4 Amp). When the rear electrode placed further back, the prevalence of cardiac arrest was 100% but some pigs experienced broken backs. The worst position for broken ks was over the ninth to twelth thoracic vertebrae. Aalhus et al (1991a) examined the effect of head to back stunning on PSE racteristics in the longissimus dorsi and semimembranosus. They concluded that there was no effect in pigs that were bled horizontally were hoisted after the carcass convulsions had stopped. However, there can be an effect in terms of accelerating the rate of pH fall and ducing paler meat, if the carcass is suspended before bleeding.

CO_2 stunning: It is surprising that most scientists accept the view that the induction of epileptiform activity following electrical stunning is adequate criterion of unconsciousness because it is supported by the observation that such activity is associated with unconsciousness in n, and yet, they are reluctant to accept similar anecdotal reports in the human on the symptomatic effects of inhaling CO_2. Carbon dioxide n unpleasant gas to inhale because it is pungent at high concentrations, and because it induces a sense of breathlessness (Gregory et al, 90). In pigs these effects would only last for the initial period of inhalation but they may be sufficient to render the method unpleasant or n inhumane.

slid (1992) has re-emphasised that the onset of high amplitude low frequency activity in the electroencephalogram precedes the onset of nvulsive activity in the pigs. However, this does not prove that they do not experience any unpleasantness in the intervening period. arly this issue still needs investigating as there is no consensus.

It is recognised that pigs vary in the way they react to CO_2 inhalation.Troeger & Woltersdorf (1991) found that halothane positive p more violently during the convulsive phase in comparison with halothane negative pigs. However, high concentrations of CO_2 (85-9 be used to suppress this activity. CO_2 can also be used to prevent broken bones and blood splash. However it will not pre production of PSE meat in halothane positive pigs, but, along with the reduced carcass kicking, high concentrations will slightly re rate of postmortem muscle acidification. It has been claimed that high concentrations of CO_2 such as this will also result in a "suffocation" because of the low oxygen levels. This view is not however supported by experience in man. Inhalation o atmospheres using inert gases (without any added CO_2) can be a stress-free almost euphoric way of losing consciousness (Ernsting It can be associated with "an abnormal sense of well-being and over confidence", and so it sounds like an ideal way to stun pigs f welfare point of view. Whether it is suitable in other respects remains to be seen. Troeger & Woltersdorf (1991) failed to induce a lasting narcosis when using hypoxia in combination with low levels of CO_2 in a limited number of pigs. Some success has, howe achieved in poultry (Mohan Raj et al, 1992).

Stunning fish: Another interesting development has been some work on assessing stunning and slaughtering methods in farm (Kestin et al, 1991). Salmon are usually killed either without stunning or with CO_2 - impregnated water, or they are concussed handheld club. When no stunning is used the gill rakers are either severed with a knife or ripped out manually and the fish is returne water to bleed to death. In the case of trout electrical stunning is sometimes used but the most common method is to take the fish out and allow them to die from lack of oxygen. In some instances the fish are placed directly into crushed ice instead of allowing them air. There is a danger that live fish packed in ice will take a long time to die, partly because their gills will be able to scavenge oxyg the ice slurry, and because the low temperature will suppress their metabolism and hence prolong their survival. The work by Ke (1991) has confirmed this fear. Cold adapted (2°C) trout took over three times longer than fish held at 14°C to lose evoked response brains, and physical activity persisted for 198 min instead of 28 min. Present research in this area is showing that trout subjected to with CO_2 in water exhibit vigorous activity when they are first immersed in that water. This activity is much more violent than that adjusted to the same pH using nitric acid, or in hypoxic water. Perhaps CO_2 in water is unpleasant to fish.

Pithing: Pithing is regarded as a potentially unhygienic procedure but it is still used in some plants in Europe as a means of co carcass convulsions. When the pithing rod is manipulated along the spinal cord the hind legs kick, but thereafter the carcass is relaxe been known for sometime that these convulsions are insufficient to influence the rate of pH fall in the biceps femoris, longissimus triceps brachii (Leach & Wilkins, 1985). Watanabe et al (1991) have just confirmed that pithing (following pole-axe stunning) had effect on post mortem ATP breakdown and pH fall in the longissimus dorsi muscle, but it did accelerate post mortem metabolism in major. This is a novel finding because hitherto few if any manipulations before or during slaughter have influenced metabolic muscle. Bearing in mind the points of attachment of this muscle to the skeleton, it is quite logical that hind leg kicking would postmortem changes. From the commercial point of view however this is of limited importance because toughness is rarely a compl this muscle.

REFERENCES

AALHUS J.L., GARIEPY C., MURRAY A.C., JONES S.D.M., TONG A.K.W., 1991a. Stunning and shackling influences on porcine longissimus dorsi and semimembranosus muscles. Meat Sci., 29, 323-334.

AALHUS J.L., PRICE M.A., SHAND P.J., HAWRYSH Z.J., 1991b. Endurance-exercised growing sheep: II. Tenderness inc change in meat quality. Meat Sci., 29, 57-68.

N D.U., PATIENCE J.F., FORTIN A., McCURDY A., 1992. The influence of pre-slaughter oral loading of acid or base on post-
rem changes in longissimus dorsi muscle or pork. Meat Sci., 32, 65-79.

IL M.H., 1991. Studies on the return of physical reflexes in pigs following electrical stunning. Meat Sci., 30, 13-21.

IL M.H., McKINSTRY J.L., 1992. The effectiveness of high frequency electrical stunning in pigs. Meat Sci., 31, 481-491.

ACK H., 1990. Gastroenteritis and inanition diarrhoea of sheep transported by ship. N.Z. Vet. J. 38, 122.

AY A.R., GRAAFHUIS A.E., CHRYSTALL B.B., 1989. The cumulative effect of nutritional, shearing and preslaughter washing
ses on the quality of lamb meat. Meat Sci., 25, 59-67.

TLER K.M., FRANK R., 1991. Pnetachlorophenol residues in porcine tissue following preslaughter exposure to treated wood
vings. J. Food. Prot., 54, 448-450.

KELENBOOM G., BOLINK A.H., SYBESMA W., 1991. Effects of feed withdrawal before delivery on pork quality and carcass yield.
eat Sci., 29, 25-30.

NSTING J., 1965. Chapter 14. In "A textbook of Aviation Physiology" (J.A. Gillies ed.) Pergamon Press, Oxford, 270-289 pp.

RNANDEZ X., MAGARD M., TORNBERG E., 1992. The variation in pig muscle glycolytic potential during lairage - an in vivo study.
eat Sci., 32, 81-91.

ORSLID A., 1992. Muscle spasms during pre-slaughter CO_2-anaesthesia in pigs. Fleischwirtsch. 72, 167-168.

RANDIN T., 1986. Good pig handling improves pork quality. Proc. 32 Europ. Meat Res. Workers Meeting 1, 105-108

REGORY N.G., AUSTIN S.D., 1992. Causes of trauma in broilers arriving dead at poultry processing plants. Vet. Rec. in press.

REGORY N.G., MOHAN RAJ A.B., AUDSLEY A.R.S., DALY C.C., 1990. Effects of CO_2 on man. Fleischwirt. 70, 1173-1174.

REGORY N.G., WILKINS L.J., 1989. Broken bones in domestic fowl: handling and processing damage in end-of-lay battery hens.
t. Poult. Sci., 30, 555-562.

REGORY N.G., WILKINS L.J., 1990. Broken bones in chickens: Effect of stunning and processing in broilers. Brit. Poult. Sci., 31,
-38.

REGORY N.G., WOTTON S.B., 1989. Effect of electrical stunning on somatosensory evoked potentials in chickens. Brit. Vet. J. 145,
9-164.

GGS A.R., 1991. National data recording system for the live sheep export industry. Misc. publ. NDRS, Australia 12/91.

GGS A.R., NORRIS R.T., RICHARDS R.B., 1991. Season, age and adiposity influence death rates in sheep exported by sea. Aust. J.
ric. Res. 42, 205-214.

OENDERKEN R., 1978. Electrical stunning of pigs. In: Hearing on pre-slaughter stunning. Meat. Res. Cen., Kavlinge, Sweden pp. 29-
.

ESTIN S.C., WOTTON S.B., GREGORY N.G., 1991. Effect of slaughter by removal from water on visual evoked activity in the brain
d reflex movement of rainbow trout. Vet. Rec. 128, 443-446.

LINGBIEL J.F.G., NAUDE R.T., 1977. Die invloed van proteienvoeding en bedwelminstegnieke op die pH en temperatuur van
arkspiere. Agroanim. 9, 31-35.

EACH T.M., WILKINS L.J., 1985. Observations on the physiological effects of pithing cattle at slaughter. Meat Sci. 15, 101-106.

ONG V.P., TARRANT, P.V., 1990. The effect of pre-slaughter showering and post-slaughter rapid chilling on meat quality in intact pork
des. Meat Sci. 27, 181-195.

MLC, 1976. Technical Bulletin Number 14, Milton Keynes, Meat and Livestock Commission.

MOHAN RAJ A.B., WOTTON S.B., GREGORY N.G., 1992. Changes in the somatosensory evoked potentials and spont electroencephalogram of hens during stunning with a carbon dioxide and argon mixture. Br. Vet. J. 148, 147-156.

RICHARDS R.B., HYDER M.W., FRY J., COSTA N.D., NORRIS R.T., HIGGS A.R.B., 1991. Seasonal metabolic factors responsible for deaths in sheep exported by sea. Aust. J. Agric. Res. 42, 215-226.

ROOS J., KOOPMANS S., 1934. Studies on the so-called electrical stunning of animals. Vet. J., 90, 232-245.

TROEGER K., WOLTERSDORF W., 1991. Gas anaesthesia of slaughter pigs. Fleischwirt. 71, 1063-1068.

WATANABE A., TSUNEISHI E., TAKIMOTO Y., 1991. Effects of pithing on pH, creatine phosphate and ATP - related compo beef psoas major and longissimus dorsi muscles. Meat Sci., 29, 221-228.

WARRISS P.D., BEVIS E.A., 1987. Liver glycogen in slaughtered pigs and estimated time of fasting before slaughter. Brit. Vet. 354-360.

WARRISS P.D., BROWN S.N., BEVIS E.A., KESTIN S.C., YOUNG C.S., 1987. Influence of food withdrawal at variou preslaughter on carcass yield and meat quality in sheep. J. Sci. Food Agric., 39, 325-334.

WARRISS P.D., KESTIN S.C., BROWN S.N., BEVIS E.A., 1988. Depletion of glycogen reserves in fasting broiler chicken Poult. Sci., 29, 149-154.

WARRISS P.D., BROWN S.N., BEVIS E.A., KESTIN S.C., 1990. The influence of pre-slaughter transport and lairage on meat q pigs of two genotypes. Anim. Prod., 50, 165-172.

WARRISS P.D., BEVIS E.A., EDWARDS J.E., BROWN S.N., KNOWLES T.G. 1991. Effect of the angle of slope on the e which pigs negotiate loading ramps. Vet. Rec., 128, 419-421.

WARRISS P.D., BEVIS E.A., BROWN S.N., EDWARDS J.E. 1992. Longer journeys to processing plants are associated wi mortality in broiler chickens. Brit. Poult. Sci., 33, 201-206.