The Stress Syndrome and Meat Quality:

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The papers in this section by Monin, Lacourt and Henry, by McLoughlin and Mothersill and my own comments are concerned with elucidation of those mechanisms at the neuro-muscular junction which control the post-mortem changes in muscle and the quality of the meat. Each paper approaches the problem from a different point of view but close analysis shows that two features of a common mechanism are being examined.

The biochemical control of the meat quality is known to rest in the pattern of pH development in muscles during the early period post-mortem. In general, the faster the rate of pH fall, the poorer, in terms of its paleness and wetness, will be the quality of the meat. It is also considered that the faster the pH falls, the lower will be the ultimate pH of the meat and this may decrease the water binding capacity of the muscle even further.

McLoughlin (1963) and Bendall (1966) examined the role of neuro-muscular stimulation in the control of meat quality. They found that if pigs were curarised for a period before they were killed, the rate of ATP breakdown and associated fall in the pH of muscle were slowed to an extent which was likely to lead to an improvement in the quality of the meat. These experiments were carried out on pigs of the Large White type. This work suggested that the quality of pig meat could be improved by modification of

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the handling procedure prior to slaughter to decrease the amount of neuro-muscular stimulation that an animal might suffer. Subsequent experiments on Pietrain (Lister, 1971) and Poland China pigs (Sair et al 1970) given the same dose of curare did not show any striking retardation in the rate of pH fall in the muscle post-mortem nor in the quality of the meat of these stress sensitive breeds of pigs.

Curare produces its paralysing effects by blocking the receptor sites on the post junctional membrane for the transmitter, acetyl choline, so that a nerve action potential is not propagated across the motor end plate to stimulate the muscle. One might conclude, therefore, that in those breeds of pigs which consistently produce meat of poor quality the abnormally high rates of ATP breakdown are not induced by nervous stimulation arising pre synaptically but rather by mechanisms, which lie beyond the motor end-plate in the muscle fibres themselves, controlling the spontaneous flux of sodium, potassium or calcium ions. A second conclusion might be that in stress sensitive pigs there is enhanced release of transmitter substances pre synaptically which impinge on more receptor sites on the motor end-plate than can be blocked by conventional doses of curare.

We examined the first proposition in Pietrain pigs (Lister 1971). In our experiments we attempted to modify the electrolyte balance on muscle membranes by inducing changes in electrolyte balance in the body as a whole. Spironolactone was given orally to pigs for about a week before slaughter to induce the retention of potassium. We fed a comparable group of pigs with a high salt diet and injected them with deoxycorticosterone for the same period of time before slaughter to induce sodium retention. The former treatment led to a deterioration in meat quality, whereas the latter led to a slight improvement. Although the induced sodium retention led to some improvement, the overall quality of the meat was still significantly poorer

than that to be expected from Large White pigs slaughtered in the conventional manner. Our conclusion was that although the flux of sodium and potassium ions across the muscle membranes might affect the sensitivity of muscle to stimulation, the effect was likely to be small and that a more important control mechanism was located elsewhere. At about this time, experimenters in the United States (Passbach et al 1970) were conducting similar experiments with spironolactone. Their pigs received the drug within an hour of slaughter and it might be considered that this period of time was not sufficient to allow the full effects of the drug to develop. Nevertheless, they recorded an effect which suggested that, if anything, treatment with spironolactone improved the quality of meat.

Monin and his colleagues, in the paper presented here, have examined the role of electrolytes in even greater detail than either Lister or Passbach and his colleagues did. They also attempted to relate water, sodium and potassium distribution in muscles of different metabolic type to potential meat quality. In the last part of their paper they examined the experimental modification of electrolyte distribution with spironolactone in the same way that Lister (1971) used it. In their experiments they used Pietrains, Large White and Large White/Belgium Landrace pigs, weighing between 85 and 110 kg. Their results showed that there were few striking relationships between ionic concentrations in muscle and meat quality yet it is interesting, although they do not comment upon this, that there were marked differences in the concentrations of sodium and potassium in the muscles from the three breed types (Table one). One might conclude from this comparison that Pietrain pigs, with their consistently inferior meat quality, have quite different concentrations of sodium and potassium in their muscles from those of ~~Large White and~~ Large White crosses which might be expected to produce better quality meat.

The data which Monin and his colleagues present for their experiments with spironolactone are difficult to interpret. The longissimus dorsi muscle, for instance, of the experimental group acidified in a similar fashion to the biceps femoris of both the control and experimental groups. Yet the water binding capacities and transmission values of the former suggested that their ultimate meat quality was better than either of the other two which themselves differed in these respects. The overall conclusion from these experiments must be that, although there is evidence that drug induced changes in electrolyte balance may modify the quality of meat, they, and spontaneous differences in the ionic composition of the muscle of living animals, are unlikely to contribute substantially to the control of meat quality.

The central role of calcium ions in the activation of the contractile mechanism and ATPase activity is of obvious importance. Yet it is difficult to identify whether the altered calcium handling characteristics of P.S.E. muscle represent cause or effect. Defects of the calcium accumulating ability of the sarcoplasmic reticulum or of mitochondria suggest attractive explanations for the aetiology of P.S.E. meat. But if sufficient care is taken in the preparation of these organelles for investigation, their usual apparent loss of functional capacity can be explained (Greaser et al 1969a, b; Cheah, 1973). It would seem that, in general, the movement of calcium in muscle continues at a rate determined by the extent to which the muscle is stimulated.

The use of curare provided one of the fist means whereby the physiological and biochemical factors determining the quality of meat could be examined under controlled experimental conditions. The observations that halothane and suxamethonium could trigger off a pattern of events in

the muscle of anaethetised animals which closely resembled that which followed the slaughter of the conscious animal, has provided another most important investigatory tool.

The development of so called malignant hyperthermia by Pietrain pigs allowed to breath halothane was described by Sybesma and Eikelenboom (1969). They also recorded the accelerated breakdown of ATP and glycolysis in muscle which preceded death. McLoughlin and Mothersill have confirmed and extended these results in Pietrain pigs. Their pigs developed a marked rigidity of the extensor muscles of the hind limbs which was not relaxed by the administration of tubocurare, nor was it induced by nitrous oxide and oxygen in the absence of halothane. In both their papers Mothersill and McLoughlin examine, in greater detail, the biochemistry and the morphology of muscle fibres separated from the red and white areas of the muscle semitendinosus of both Pietrain and Landrace pigs. Muscle specimens taken from live Pietrain pigs breathing halothane showed considerable disruption of the organized structure of the fibre which presumably was another reflection of the high rate of ATP breakdown. Muscle from Landrace pigs which did not respond adversely to halothane contained normal fibres. All of these observations lend support to the view that malignant hyperthermia and associated phenomena develop as a consequence of the hypersensitivity of muscle to stimulation.

We also have been interested in the development of malignant hyperthermia in Pietrain pigs. Our particular interest is in its endocrinology and its use as a model for the investigation of the control of meat /quality. In our experiments we have used suxamethonium as a triggering agent. We have found that the administration of two doses of 50 mg of suxamethonium to a Pietrain pig anaethetised with thiopentone and ventilated with nitrous oxide and oxygen provides a reliable triggering agent for the induction of a

hyperthermic response.

Thyroid hormone has also been implicated as an important factor in the development of this response (Lister 1973). There is a decline in the Free Thyroxine Index which has now been shown to occur simultaneously with, and may be the result of, a massive increase in catecholamines, predominantly nor adrenaline. In view of this, and earlier suggestions of the possible involvement of catecholamines in the control of meat quality, we have investigated the effect of alpha and beta adrenergic blocking drugs on the suxamethonium triggered response (Lister, Hall and Lucke 1974). Beta blockade was established in Pietrain pigs by the intravenous infusion of 40 micrograms per kilogram per minute of dl propranolol for about 30 minutes before suxamethonium was given. Despite the prior treatment and continued infusion of the drug for the duration of the experiment, all the pigs developed acidoses, raised serum potassium and blood glucose, rigor and fever and died in exactly the same way as those which received no prior treatment with blocking drug. The only beneficial effect of propranolol was on heart rate which declined slightly from the pre-triggering values.

Another group of Pietrain pigs was infused in exactly the same fashion but with 50 micrograms per kilogram per minute of phentolamine, an alpha blocking drug. Again suxamethonium was administered after 30 minutes, but in this case the metabolic changes were minimal and all of the pigs survived. There was, however, a large increase in heart rate in these alpha blocked animals which was easily controlled by the administration of 1-2 mg of propranolol. We concluded from these experiments that the untoward reaction of pigs to suxamethonium is attributable to an alpha adrenergic mediated response. The basic mechanism involved is likely to be the augmentation of transmitter release at the neuro-muscular junction by catecholamines. It

may also account for the potentiation of the action of suxamethonium by these hormones and their anti-curare effect (see Bowman and Nott 1969).

In order to confirm our belief in a common aetiology for both malignant hyperthermia and the control of meat quality in breeds of pigs like the Pietrain, we administered to slaughter pigs the same amounts of either alpha or beta blocking agents which we had given in the experiments just described. This time, however, the drugs were given in single doses to conscious pigs half an hour before slaughter by conventional methods. It was clear from our earlier experiments that, for protection against suxamethonium, massive doses of blocking agent were required to create the necessary level of blockade. We found that the amounts of catacholamines in the serum at slaughter could be up to 200-300 times the resting level, and were so great that the dosage of blocking agent which had been sufficient to create block in anaethetised animals was not nearly adequate in conscious animals. Neither was there a substantial improvement in the quality of the meat (see Table 2). Moreover, there appeared to be no difference between alpha and beta blocking agents in their effect on meat quality. This kind of result has been found by previous workers (Topel et al 1973). We suspected, however, that this result arose from our inability to create adequate blockade, and in order to achieve this we anaethetised the animals prior to treatment with blocking agents. Our suspicions proved to be correct and we were able to show that adequate alpha blockade led to a significant and striking improvement in the quality of the meat (see Table 2). We also concluded that the beneficial effect of beta blockade of conscious animals resulted from the local anaesthetic properties of the drug for it was clear that β blockade and general anaesthesia, did not improve meat quality beyond that resulting from general anaesthesia alone.

We suggest on the basis of these findings, therefore, that the impaired meat quality of Pietrain pigs is a consequence of the enhanced release of neuro-transmitter, during physical stimulation. It is also of note in this connection, that McLoughlin (personal communication 1974), when he administered sufficiently large amounts of curare, was able to slow glycolysis significantly, even in Pietrain pigs. We have since been able to confirm this in our laboratory.

The question remains as to why Pietrain pigs should have this peculiar hormonal pattern which confers on them hypersensitivity to stimulation and results in their consistently producing meat of inferior quality or their premature death. Evidence which we are currently assembling (Wood & Lister - in preparation) allows us to conclude that the particular hormonal pattern responsible for the hypersensitivity is part of the mechanism which, in lean animals like the Pietrain, allows them to restrict their deposition of fat.

Thus it seems that animals which, like the Pietrain, produce their lean and shapely carcasses by this route must inevitably produce meat of inferior quality. We must ensure, therefore, that animal breeders recognise this as a potentially limiting factor in their search for the extra lean pig.

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Table 1

The concentrations of Na^+ & K^+ in pig muscle

(after Monin, Lacourt & Henry 1974)

Experiment No.	1		2		3			
Breed	Large White & Pietrain		L.W × Belgium Landrace		Pietrain			
Treatment	None		None		None		Aldactone	
Muscle	BF	LD	BF	LD	BF	LD	BF	LD
Total Na^+ ± se (meg/kg wet wt)	20.6 ±1.4	16.9 ±1.0	16.0 ±0.4	14.7 ±0.6	21.9	20.3 (calculated)	19.5	18.7
Total K^+ ± se (meg/kg wet wt)	98.9 ±3.9	97.0 ±6.3	82.3 ±3.6	102.8 ± 3.2	120.4	127.1 (calculated)	126.7	134.7

Table 2

The effects of anaesthesia, α and β adrenergic blockade on meat quality in Pietrain pigs

(from Lister & Wood - in preparation)

Treatment	Electrical stunning	'Loin chops' EEL Value	'Loin chops' Drip % lean
Controls	+	52 ± 1.7	6.7 ± 0.37
Propranolol (2 mg/kg)	+	48 ± 2.6	5.4 ± 0.28
Phentolamine (2 mg/kg)	+	45 ± 2.1	5.3 ± 0.32
Anaesthesia (Thiopentone)	-	41 ± 1.7	3.5 ± 0.23
An + Propranolol (2 mg/kg)	-	42 ± 1.9	3.7 ± 0.25
An + Phentolamine (2 mg/kg)	-	39 ± 1.2	1.5 ± 0.17