A.A.Taylor.

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## Influence of Carcass Cooling Rate on Exudate from Meat

The abnormally high drip loss from pale, soft, exudative (P.S.E.) muscle has been attributed (Bendall, 1960; Bendall & Lawrie, 1964; Briskey, 1964; Callow, 1958; Hamm, 1960; Krzywicki, 1968; Lawrie, 1966; Wismer-Pedersen, 1958; Wismer-Pedersen & Briskey, 1961) to unusually rapid rates of glycolysis in the first few hours after slaughter. The extent of this drip loss depends on time, temperature and pH (Penny, 1969) and it is reasonable to suggest that, even with normal rates of glycolysis, a relationship exists between rate of cooling after slaughter and the occurrence of drip in jointed carcasses. This investigation was carried out to examine the relationship applied to pig and beef carcasses.

### Experimental

The pigs used in these experiments weighed 40-60 kg and comprised Landrace, Large White, Wessex x Large White and Pietrain breeds. The last of these is particularly prone to give P.S.E. muscle (Bendall, Cuthbertson & Gatherum, 1966; MacDougall & Disney, 1967; Lister, 1970). The Pietrains were hauled 100 miles, held locally for at least a week and brought into lairage a day before slaughter; all the others were obtained Locally and held in lairage overnight before slaughter. The pigs were electrically stunned and shackled by both legs before normal slaughter at the Meat Research Institute.

### Chilling

Temperature changes during cooling were recorded by thermocouples placed deep in the leg and in the longissimus dorsi muscle. The variation between animals was eliminated by comparing only sides of the same carcass after they had been cooled at different rates.

Pig sides were cooled at 2 rates (Fig. 1).

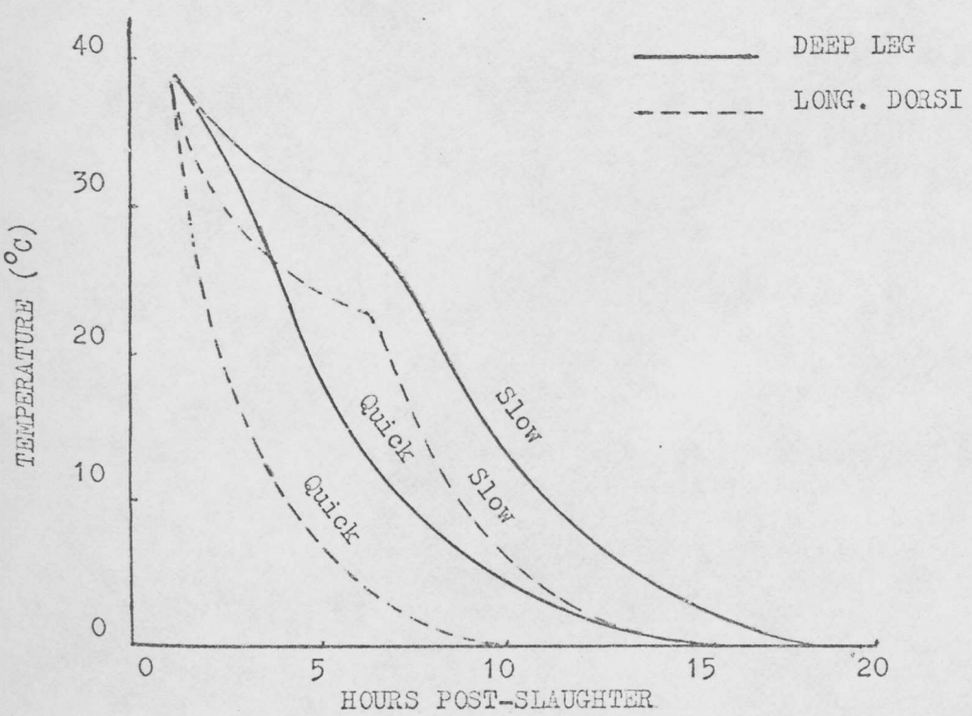


Fig. 1. - Temperature changes in long. dorsi and deep leg of pig sides cooled slowly and quickly to 0°C.

(a) Quick - Sides were placed in chill at 0°C, in still air, 30 minutes after slaughter and cooled for a total of 24 hours.

(b) Slow - Sides were held at 20°C for 6 hours before going into chill at 0°C, in still air.

Beef sides were cooled for 48 hours at different rates, again comparing only sides from the same carcass. Four different rates were obtained by using the following conditions, commencing 1 hour after slaughter (Fig. 2).

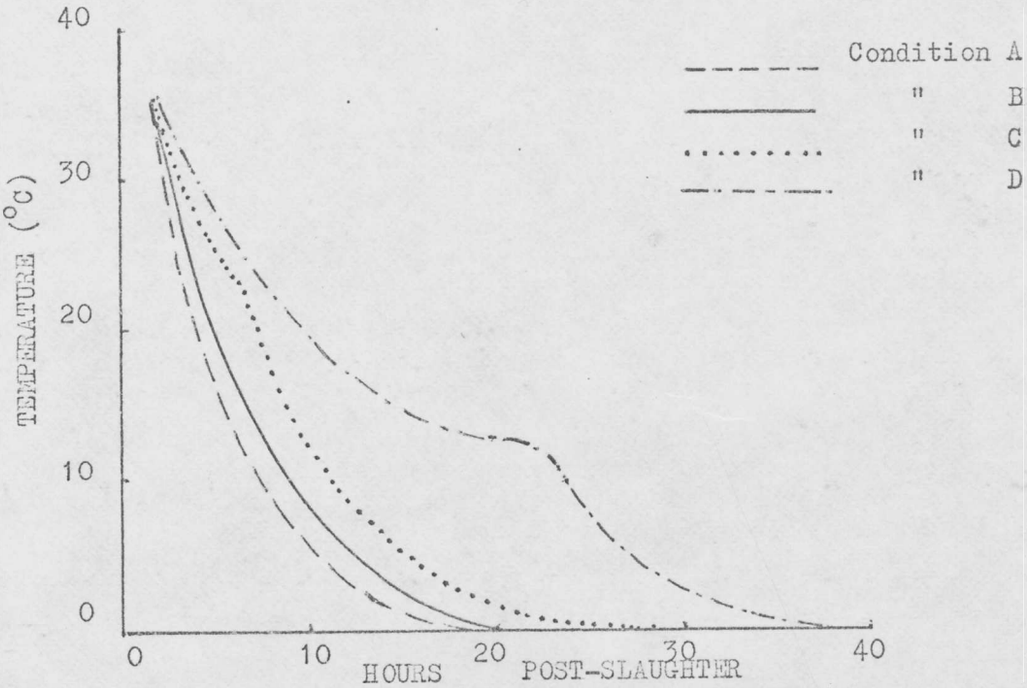


Fig. 2. - Temperature changes in long. dorsi of beef sides cooled to 0°C under conditions A, B, C and D.

(A) - 23 hr. at 0°C (Air at 1-2 metre/sec.) + 24 hr. at 0°C (Still air)
(B) - 47 hr. at 0°C (Still air)
(C) - 6 hr. at 15°C + 41 hr. at 0°C (Still air)
(D) - 23 hr. at 15°C + 24 hr. at 0°C (Still air)

These conditions were chosen as being within the range of cooling regimes currently used in the meat industry.

pH was measured, using a probe electrode, in the longissimus dorsi, at the last rib, of both pig and beef carcasses. Measurements were made at 0.5 hr. (pigs), 1 hr. (beef) and ultimately at 24 hr. (pigs) and 48 hr. (beef). The early pH was used to indicate the initial rate of pH fall and rate of glycolysis (Wismer-Pedersen, 1958).

Preparation of Samples Earlier experiments (Taylor & Dant, 1971) had established that drip in jointed carcasses occurred in a consistent pattern and that individual joints could be selected to reflect the exudate lost from the carcass as a whole. In the experiments with pigs, the knuckle-end joint was used for comparison in some cases, while in others the drip from four

principal leg muscles was compared. These muscles, semimembranosus, semitendinosus, adductor and biceps femoris, were cut transversely to give halves with cut surfaces for drip estimation. In the beef experiments slices 1" thick, were cut from the longissimus dorsi at the 9th-10th ribs. Drip after 48 hours at 0°C was estimated, in the usual way, on 4 such slices from each beef side.

Drip estimation The method for estimating drip loss was designed to relate easily to practical conditions. Joints or muscle samples being examined were weighed and placed in polythene net which supported the meat without covering its surface. The samples were then suspended in sealed polythene bags hung in a chill room at 0°C. After 48 hours, the drip which had accumulated in the bag was weighed.

Results and discussion

Pigmeat Although the amount of drip varied with breed, the effect produced by the different cooling rates was highly consistent in these experiments. When 40 paired legs (10 from each breed) were compared, the advantage of the quicker cooling rate was demonstrated in all but 2 pairs. The mean overall drip after 48 hours from the quickly cooled legs was 0.47% by weight while that from their slowly cooled counterparts was 0.83%.

Similarly consistent results were obtained when excised leg muscles were compared. Paired muscles from 19 pigs (6 Large White + 13 Pietrain) were used and the mean drip values for each muscle after the two cooling rates are shown in Table 1.

Table 1 - Mean percentage drip by weight from four muscles excised from pig sides cooled slowly and quickly.

| | % Drip after 48 hours at 0°C | | | | |
|---|---|---|---|---|---|
| Cooling rate | Semitendinosus | Semimembranosus | Adductor | Biceps femoris | Combined (4 muscles) |
| Slow | 2.97 | 4.98 | 5.84 | 3.21 | 4.25 |
| Quick | 2.25 | 3.20 | 4.22 | 1.86 | 2.89 |

All the muscles had less drip when quickly cooled although the individual amounts varied. The ultimate pH values of the four muscles in any one carcass were not sufficiently different to account for one muscle exuding more than another. The general level of the figures in Table 1 is exaggerated to some extent by including a majority of Pietrains which averaged, in these experiments, approximately 1.8 times as much drip as the Large Whites. The variability in the level of drip was not only between, but also within breeds. When drip was examined in relation to $pH_{30}$ (pH at 30 minutes post-slaughter) it was observed that, in the experiment comparing leg joints, only 7 out of 40 pigs had $pH_{30}$ below 6.1. This is the level below which one might expect to find evidence of P.S.E. muscle (Penny, 1969) and it was significant that joints from these pigs, although not pale, tended to have more than average drip. The majority of the pigs used however, had $pH_{30}$ values well above 6.1 indicating normal rates of glycolysis after slaughter.

It is well-known (Bouton, Lawrie & Howard, 1957) that abnormally high ultimate pH in meat, due to excessive depletion of glycogen before slaughter, can reduce drip by increasing the water holding capacity of the muscle. In these experiments the levels of ultimate pH were quite normal as would be expected with animals well-rested before slaughter. The normality of the post-slaughter glycolysis and the ultimate pH values suggest, therefore, that the reduction in drip loss was caused mainly by the quicker carcass cooling.

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Beef - The greater muscle bulk in beef carcasses results in slower cooling rates than those found with pigs, and 48 hours were required to bring the carcass temperature to 0°C. Since 4 sets of cooling conditions were used with beef sides, the effect of different cooling rates on drip was best demonstrated by the ratio of drip produced in samples from each pair of sides under the two cooling conditions being compared. The figures in Table 2 are the mean ratios obtained from cooling a total of 28 carcasses.

Table 2 - Mean ratios of drip loss, after 48 hours at 0°C, from longissimus dorsi samples removed from slowly and quickly cooled beef sides.

| Cooling methods | | Drip (Slow cooling) / Drip (Quick cooling) |
|---|---|---|
| Slow | Quick | |
| C | A | 2.2 |
| D | B | 2.4 |
| D | A | 2.9 |

The advantage gained by cooling quickly soon after slaughter is clearly shown by these figures. The amount of drip varied between animals but, as an indication of the levels of exudate, the mean loss after 48 hrs at 0°C from long. dorsi samples taken from sides cooled quickly by method (B) was 1.07% by wt. while that from sides cooled at the slowest rate (D) was 2.65%.

The pH, 1 hour after slaughter of all the beef carcasses lay in the range 6.5 to 7.0 with a mean of 6.8. The ultimate pH at 48 hours ranged from 5.6 to 5.8 with a mean of 5.7. Such pH levels indicated no abnormality in post-portem rates of glycolysis. The reduction in drip with the quicker cooling rates, was therefore attributed to the lower temperatures in the muscle, especially in the early post-slaughter period.

Only part of the longissimus dorsi was studied in the beef experiments and it is too early to say conclusively that such samples are necessarily representative of the behaviour of the whole carcass. It is reasonable to assume, however, after the pig studies, that the drip levels in other parts of the beef carcass will be reflected to a certain extent by the drip in the longissimus dorsi.

It has been demonstrated that the amount of drip in fresh pigmeat and beef is influenced by the rate of carcass cooling, especially in the early period after slaughter. The cooling rates used in these experiments did not approach the rapid rates which can be achieved with faster air movement at lower temperatures. While it is important to avoid cooling muscle too quickly as this can lead to cold-shortening and toughness in some cases (Locker & Hagyard, 1963), air speeds of up to 10m/sec and initial temperatures of -5°C are obtainable in rapid chilling systems, and the initial cooling provided by such conditions, especially in the case of beef carcasses, could give even greater reduction of drip loss than that observed in this investigation.

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