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QUALITY OF FRESH AND FROZEN BEEF AS A FUNCTION OF PRESLAUGHTER TREATMENT

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Immediately after the war ended the meat industry in Australia was naturally concerned with the question of the relative positions chilled and frozen beef were likely to occupy in its future export programme, when the rationing of meat in the United Kingdom - Australia's natural market - would be discontinued. While frozen beef has much to recommend it from the point of view of ease of production and transport it suffers primarily from the occurrence of "drip" - i.e. the exudation of a reddish viscous fluid from thawed out frozen meat. This factor, together with difficulties in providing thawing facilities and the obvious difference in appearance from unfrozen beef, has created a prejudice against frozen beef which is not necessarily justified on the basis of eating quality.

These considerations resulted in a joint programme of investigations by the Department of Scientific and Industrial Research of the United Kingdom and the Commonwealth Scientific and Industrial Research Organization of Australia to determine the factors involved in the changes associated with freezing and the extent to which these changes, and the initial quality of the meat, could be modified. A large part of this programme was devoted to the influence of preslaughter factors.

The extent of drip from muscular tissue which has been frozen and then thawed out is influenced not only by intrinsic factors, such as species, muscle and beast, but also by conditions or treatment at all stages throughout the growth of the animal and the handling of the carcase (Empey and Howard 1951). In the cooperative work particular attention was given to those conditions which affected the extent of production of lactic acid in the muscular tissue post mortem and the rate of development of rigor mortis. The influence of pH on drip has been recognised for a long time. Empey (1933) showed that when animals yielded meat which had a pH well above 6, drip was greatly reduced. This finding has been confirmed repeatedly. Although muscles at any given pH show consistent differences in the extent of drip, it has also been shown that within any one animal there is superimposed on these differences between specific muscles a general relation of decreased drip with increased pH (Howard, unpublished). On the other hand, increase of pH is generally recognised to be associated with reduction in quality and increased rate of bacterial attack (Callow 1935-9; Bate-Smith 1948).

That the dynamics of the development of rigor mortis might be reflected in changes in the extent of drip is a newer concept arising from recent advances in our knowledge of the physicochemical nature of muscular contraction and relaxation, and of the water binding properties of muscle proteins (Bendall and Marsh 1950; Bergh 1952; Howard and Lawrie 1956a). The premise is that a slow rate of development of rigor mortis should restrict loss of fluid as drip. The present series of investigations therefore set out to establish the extent to which the rate of development of rigor mortis and the extent of post mortem lactic acid production could be influenced in the steer carcase by preslaughter conditions and how any such changes would be reflected in drip and eating quality.

The general biochemical pattern of the development of rigor mortis in the steer (Howard and Lawrie 1956b, 1957a) was found to be similar to that in laboratory animals with respect to the relations between pH, labile phosphorus compounds and extensibility of muscle fibres. There is, however, one important difference which distinguishes the normal steer from small laboratory animals such as the rat and rabbit, from the pig and, to a smaller extent, from the sheep. This factor is the quantity of glycogen stored in the muscles. With the smaller animals the amount of glycogen present in any particular muscle is usually less than 0.8%. This is the quantity necessary for the production of sufficient lactic acid to attain a pH of 5.4, at which the glycolytic enzymes appear to be inhibited. In the muscles of small animals, all the glycogen can thus be converted to lactic acid and the ultimate pH is a function of the amount of glycogen present at slaughter. In the muscles of the steer, however, it is normal to find glycogen considerably in excess of 0.8%, values of 1.5% being common in a well-fed rested animal. Consequently beef muscle may frequently contain considerable residual glycogen at a pH of 5.4. Moreover in the steer under conditions of fasting and exercise, it appears that glycogen reserves are normally lowered only to a point approximating to 0.8 per cent. Presumably other energy sources are then drawn on by the animal. In the muscles of such fasted or exercised animals after slaughter the ultimate pH is again of the order of 5.4 but there is little or no residual glycogen. Only where the exercise is given immediately after long periods of rail transport has there been evidence that glycogen levels can be diminished below 0.8% - with consequent increase in ultimate pH.

It has been possible to obtain quite large increases in pH by more drastic treatment. When sufficient insulin was injected to produce tetany, the reserves of muscle glycogen were depleted to varying extents. In an extreme case a musculature with an average pH of slightly over 7.0 was obtained. Elevated values of ultimate pH have also been obtained by injection of sufficient tuberculin to cause protein shock and intensive tremor and also by exercise, following fasting and injection with neopyrithiamin (to inhibit the oxidation of fatty metabolites.) However the response of individual animals to such treatments was very variable. As a result it is much more difficult to make a statement about the effect of any particular treatment on drip or quality than it is to consider the general relationship between pH and these criteria. Another example of animal variability was the occurrence of a typically low glycogen levels, and high ultimate pH values, in a few well fed rested steers in a group of uniform origin. In one case a steer which had been rested and supplied with liberal food for several months gave an ultimate pH ~~value~~ of 6.0 in the l. dorsi and 6.3 in the psoas. The cases where this was noted were invariably associated with a marked "excitability" and with difficulty in handling in the pens. An abnormal endocrine condition appeared probable but prolonged administration of thyroxine or thyroid extract to docile steers, and of thiouracil to excitable steers, did not produce any noticeable effects in behaviour or on glycogen level. Treatment with adrenalin or ephedrine was equally ineffective.

While the treatments which have been used to effect changes in the ultimate pH of beef may have little relation to conceivable practical conditions they have provided a wide range of values of pH from which the influence of this factor could be studied with respect to drip and eating quality (Howard and Lawrie 1956c, 1957b). The effect of high pH in diminishing drip has again been confirmed, both for small sections of meat similar to those used by the earlier workers and also for larger cuts such as are used in retail trade. Although there are evident differences in the general tendency to drip between muscles, the influence of pH is similar (Fig. 1).

In assessing quality, the appearance of the uncooked meat was recorded and 3 joints from each carcase were cooked and scored by a panel for odour, flavour, tenderness, juiciness, colour and overall acceptability. While all of these characteristics are subject to variations arising from the individual animal and the conditions at the time of slaughter and examination, it has, nevertheless, been possible to establish that in the case of appearance of the fresh meat, and of the flavour, tenderness, colour and general acceptability of the cooked meat, there is a definite pH effect superimposed on the effects of other variables. With increasing pH the meat flavour decreases and the colour of the fresh and cooked meat darkens. Tenderness decreases until the pH reaches approximately 6.0 and then increases again. However the textural changes associated with this later increase in tenderness were not liked by the tasting panel and the overall acceptability decreased throughout the pH range. Such changes in eating quality are illustrated by Figs 2-4. Where the pH is high there is also a tendency for low weight losses in cooking, in agreement with the analogous relation with drip.

Animals were also given treatments which, it was considered, might alter the rate of development or *rigor mortis* without influencing the ultimate pH. From analogy with *in vitro* experiments, the levels of Ca and Mg ions in the blood and hence, possibly, in certain sites within the muscle fibre were expected to influence the rate of development of *rigor mortis*. Similarly, pyrophosphate was expected to have an influence either in simulating the Marsh-Bendall factor (Bendall 1953) or in modifying the level of Ca and Mg ions through its chelating action. Peripheral relaxation was also expected to delay onset of *rigor mortis* by restricting the production of lactic acid from struggling at or immediately before death. Pronounced changes in the time course of *rigor mortis* were in fact obtained by some of the treatments. Hypercalcaemia, maintained for a period of 30 minutes by injection of calcium borogluconate, produced a marked reduction in the time for development of *rigor mortis* while hypocalcaemia, produced by injection of EDTA to the stage of incipient calcium tetany, gave evidence of delayed onset of *rigor mortis*. Hypermagnesaemia (without relaxation) induced by injection of magnesium sulphate, produced marked delay in the development of *rigor mortis*. Relaxation with "Myanesin", while it delayed the initial pH changes, failed to retard the onset of *rigor mortis*. Relaxation induced by magnesium sulphate effected results similar to those associated with milder non-relaxing doses of the drug. Pyrophosphate injections induced rapid onset of *rigor mortis* accompanied by other symptoms of physiological disturbance. However in spite of these marked physiological and biochemical responses to the applied treatments there was practically no evidence of any relation between rate of development of *rigor mortis* and the production of drip or the eating quality of the meat. The only effect for which there was any evidence was a possible increase in the extent of weight losses during cooking due to pyrophosphate treatment - a finding which, if real, would be at variance with the *in vitro* effects of pyrophosphate in increasing the water holding capacity of minced meat (Bendall 1954).

Variation in the rate of development of *rigor mortis* does, however, appear to be a factor in determing the rate of development of microorganisms in beef when stored in the unfrozen condition (Brown and Meaney, unpublished data). Measurements of rates of growth of psychrophilic organisms on mince preparations from animals treated to give changes either in ultimate pH or in rates of development of *rigor mortis* showed that the results could not be explained wholly in terms of the well known relationship between pH and rate of growth of organisms. The latter was also dependent on the rate of development of *rigor mortis*, the growth rate at a given pH b ing greatest when *rigor mortis* developed quickly. No explanation is as yet available for this relationship.

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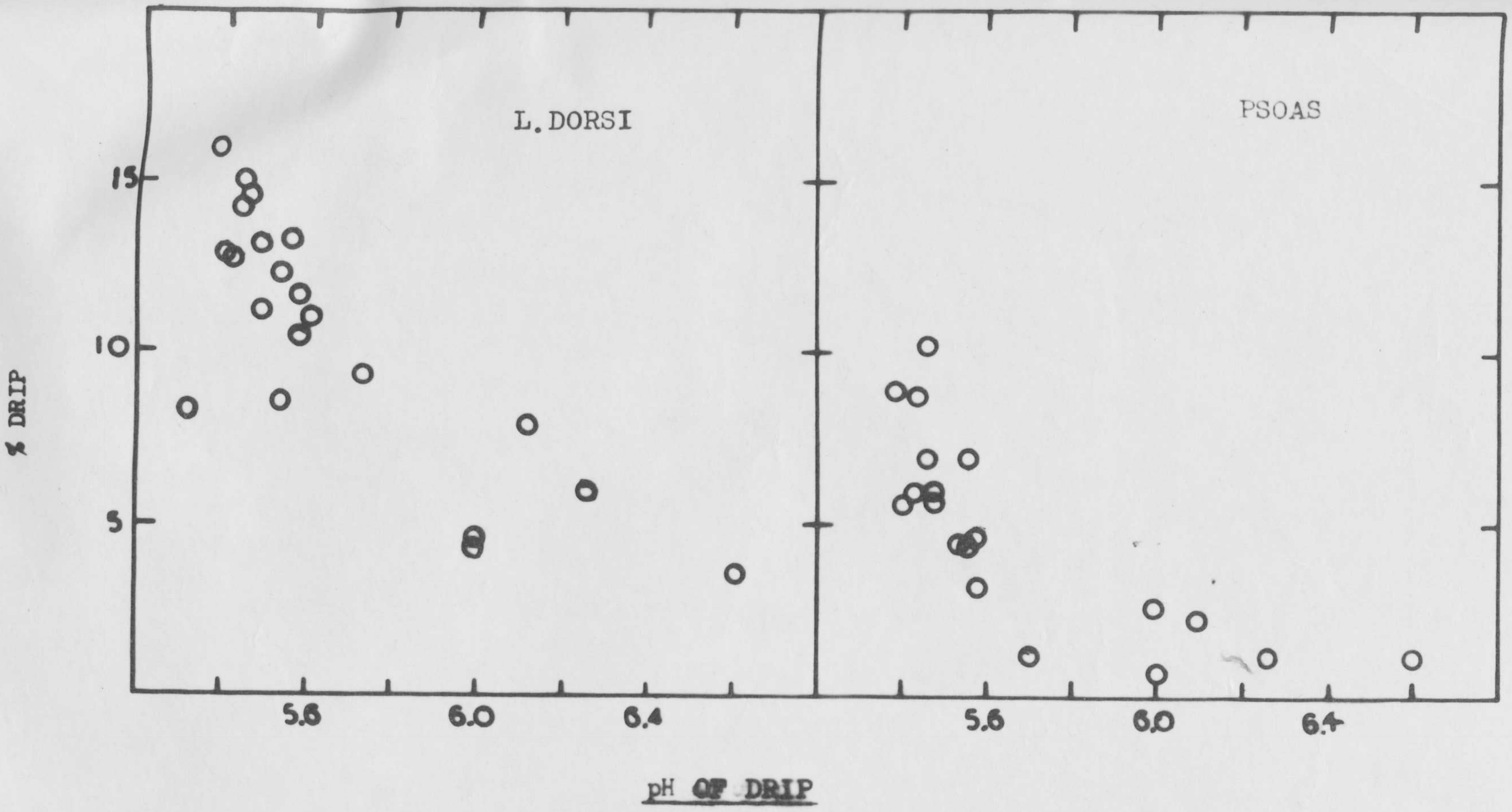

FIG. 1 RELATION BETWEEN DRIP FROM PSOAS AND L. DORSI MUSCLES AND pH OF THE DRIP

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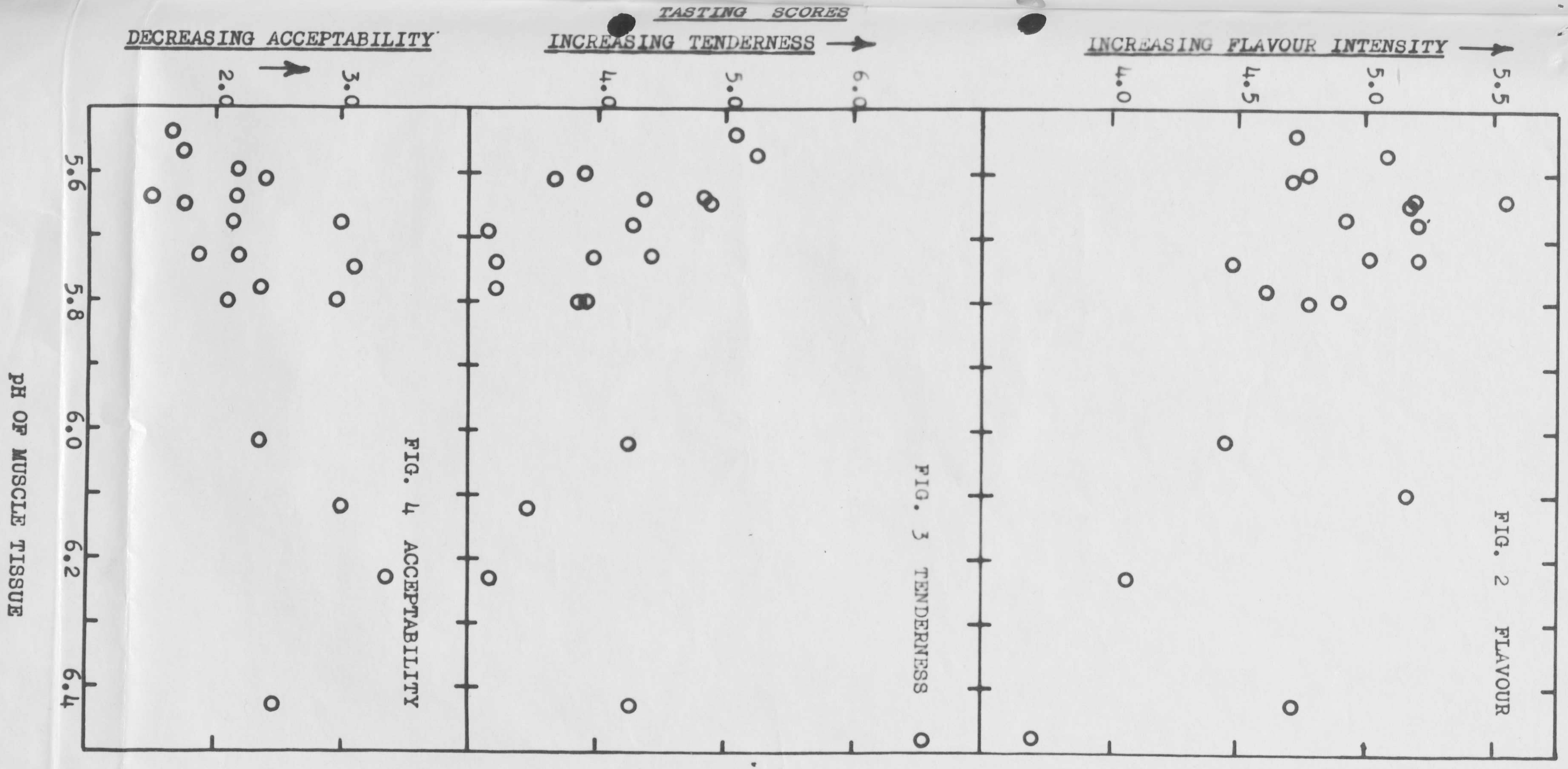

FIGS. 2-4 RELATION BETWEEN TASTING SCORES AND pH OF MUSCLE TISSUE