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Observations on British Heavy Hogs handled in a Factory Slaughterline.

D.J.Locke and R. Vetterlein.

T. WALL & SONS (MEAT AND HANDYFOODS) LTD.,
Atlas Road, Willesden, London N.W.10.

OBSERVATIONS ON BRITISH HEAVY HOGS HANDLED IN A FACTORY SLAUGHTERLINE.

D. J. Locke and R.Vetterlein
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The traditional approach in the United Kingdom to the Factory utilisation of pig meat has required two weights of pigs. The "bacon" or "Wiltshire" pig of 150 lbs. (68Kgm) dressed weight needs a special finishing feed technique to provide the desired lean and fat conformation and qualify for the payment of a U.K. Government subsidy and a Quality Premium. On the other hand the "manufacturing" pig was raised in a manner compatible with the prevailing agricultural conditions. Any reasonable weight pig was acceptable for manufacturing purposes.

Recent consideration of the economic expansion of pig production has given rise to the concept of a rapidly growing multi-purpose animal supplying the demands of bacon and ham production as well as other manufactured items using comminuted pork. The British "heavy" hog is the result of these considerations. At 210 lbs. (95.3Kgm) dressed weight, it fulfils the consumer demand for more lean meat in bacon and ham while providing tissue fat for lard production and other manufacturing purposes. The basic division of the carcase into shoulders, middles and legs of uniform size and conformation has needed new methods of handling and processing. A method of bacon manufacture from trimmed boned middles has been described at a previous meeting (1).

There has been renewed interest in many quarters in the immediate pre- and post-mortem conditioning of carcases and the suitability of their meat for various cured and comminuted products. Our research has been directed towards any differences between traditional and heavy hogs that may be noticed as processing variability. For instance, the consistently heavier weights of hogs, together with greater thicknesses of insulating superficial fat, up to 2.5 inches (6.35 cm.) have necessitated closer control of the loading and spacing of carcases in the chillrooms, to achieve uniform and fast cooling. Our experiments have shown the variations which can be expected and the advantages to be gained by a more rapid method of chilling.

1. Comparison of hogs, a) put first into an empty chillroom, b) put last into the same but loaded chillroom.

Dressed carcases enter the chillroom approximately 30 minutes after slaughter. When empty the chillrooms are cold, but as carcases enter, hot from the slaughter line, the air temperature rises. This rise should be kept to a minimum as Bendall and his co-workers (2, 3)

have suggested that degradation of the quality of pork meat (low pH, watery and with a pale colour) can be prevented by reducing its temperature post-mortem to below 30°C. (86°F.) as quickly as possible. During the chillroom loading period (45 minutes at 320 hogs/hour) the hogs first into the chiller experience a faster chilling rate in the first 60 minutes after slaughter than do those last into the loaded room.

We investigated i) the temperature fall after 2 hours,
ii) the pH fall after 2 hours, and
iii) lean meat colour score, 24 hours post-mortem
of the m. longissimus dorsi at the 5th rib of hogs in chill.

Table 1. Properties of the m. longissimus dorsi at the 5th rib of hogs experiencing the usual Factory chilling variations.

	Hog Lot A		Hog Lot B		Hog Lot C		Hog Lot D	
	First in	Last in	First in	Last in	First in	Last in	First in	Last in
Mean temperature fall °C. (°F.) during first 2 hours in chill.	10.2 (18.4)	11.3 (20.3)	11.5 (20.7)	12.3 (22.1)	11.2 (20.1)	11.3 (20.3)	10.4 (18.7)	11.3 (20.4)
Mean pH fall during first 2 hours in chill.	0.26	0.44	0.31	0.48	0.36	0.58	0.23	0.51
Lean meat colour score 24 hours post-mortem.	2.6	3.1	2.9	3.0	3.6	2.9	2.9	2.8

Notes: i) Each hog lot represented a different feeding regime and comprised 8 animals.

ii) Temperature was measured using a thermistor probe unit.

iii) pH was measured with a temperature-compensated single probe pH meter.

iv) The lean meat colour score was a visual rating, on a five point scale (1 Excellent, 3 Average, to 5 Poor).

From Table I it will be seen that during the first 2 hours in chill, the

temperature of the pigs last in has been reduced consistently more than that of pigs first into the chiller. But the rate of temperature reduction of the pigs last in must be less during the short critical post-mortem period when glycolysis occurs most rapidly. This will be seen from the comparable pH falls during the same period. The effect, on the "24-hour" colour of the lean meat, of a rapid pH fall is reflected in the colour scores of Lot A. Less marked in the case of Lot B, the results in Lot C and D are reversed suggesting the operation of other factors affecting lean meat colour as well, more greatly in the case of Lot C than of Lot D.

The removal of heat from carcases by forced cold air circulation is obviously not as effective as removal by contact with a cold fluid medium. As a compromise experiment the following comparison of normal chilling with ice cooling was carried out.

2. Comparison of hogs chilled by two methods, a) quick chilling (sides immersed in flake ice for 2¼ hours) and b) normal chillroom chilling.

Eight sides from four hogs were selected at the end of the carcase dressing line. Temperatures were measured at the 5th rib in the l. dorsi muscle and 2.5 inches (6.35 cm.) deep in the ham. The sides were then enveloped in polythene bags and immediately surrounded with flake ice. Eight control sides from another four pigs from the same pig producer and delivered in the same lorry, were moved into the chillroom in the normal manner. Similar temperature measurements were made on these sides as quickly as possible, usually within 10-15 minutes of the readings of the sides in ice. After 2¼ hours the ice chilled sides were put into the same chillroom and the temperature of the two lots again noted.

Table 11. Effect of chilling method on temperature reduction of carcases.

Temperatures °C. (°F.)

Treatment	l. dorsi 5th rib		Left ham.		Right ham	
	Initial temp.	2¼ hr. temp.	Initial temp.	2¼ hr. temp.	Initial temp.	2¼ hr. temp.
a) Ice chilled	40 (104)	18.2 (65)	40 (104)	25 (77)	40.5(105)	29.5(85)
	39.4(103)	15.5(60)	40 (104)	22.9(75)	40 (104)	31.1(88)
	38.9(102)	25.6(78)	39.4(103)	30 (86)	39.4(103)	20 (68)
	39.4(103)	18.9(66)	40 (104)	26.1(70)	39.4(103)	24.5(76)
b) Chillroom chilled.	36.7(98)	24.5(76)	37.8(100)	29.4(85)	37.8(100)	30 (86)
	37.8(100)	26.1(79)	38.2(101)	28.9(84)	38.2(101)	29.5(85)
	35 (95)	24.5(76)	37.2(99)	27.8(82)	37.8(100)	30 (86)
	35.6(96)	27.2(81)	38.3(101)	28.3(83)	38.3(101)	30 (86)

It will be seen from Table 11 that the l. dorsi can be cooled by 19-22°C. (35-40°F.) under the best ice chilling conditions and the hams by about 14°C.(25°F.) in 2¼ hours. Comparable normal chillroom chilling temperatures were lowered by 11°C. (20°F.) and 8°C. (15°F.) respectively.

In this experiment, changes in processing character were assessed. It was noted that the quicker chilled hams provided a better cooked yield when cured by a multi-needle injection technique.

Much of the work associated with the development and feeding of the best strain of British heavy hog has required one side of the animal for lean and fat dissection and the other side for product evaluation. Shackling of the pig by one leg for sticking and bleeding could give rise to unilateral differences due to muscle strain during the agonal period.

3. Comparison of left and right sides of hogs in terms of the pH. (24 hour post-mortem) of the m. longissimus dorsi at the 5th rib.

Table 111.

pH (24 hours p-m.)

	Left.	Right.	Difference.
	5.58	5.42	+ 0.16
	5.60	5.89	- 0.29
	6.00	5.90	+ 0.10
	5.65	5.93	- 0.28
	5.82	6.07	- 0.25
	5.55	5.47	+ 0.08
	5.81	5.88	- 0.07
	5.62	6.09	- 0.47
	5.69	5.53	+ 0.16
Average	5.70	5.80	- 0.10

Note: i) The pH was measured in the minced undiluted samples 24 hours post-mortem using a bench pH meter.

The difference between the left and right sides are mathematically not significant ($p > 0.1$)

4. Comparison of sides from hogs shackled by designated legs.

The differences in pH between left and right sides of a carcase noted in Table 111 prompted a closer study in relation to the shackled leg.

Table 1V. pH and oxygen uptake of l. dorsi at the 5th rib of left and right sides of hogs shackled by designated legs.

	9 hogs shackled by left leg.			9 hogs shackled by right leg.		
	Left.	Right.	Difference.	Left.	Right.	Difference.
pH.	5.40	5.41	+ 0.01	5.46	5.43	- 0.03
	5.39	5.40	+ 0.01	5.37	5.32	- 0.05
	5.50	5.45	- 0.05	5.45	5.40	- 0.05
	5.53	5.51	- 0.02	5.83	5.80	- 0.03
	5.50	5.70	+ 0.20	5.64	5.78	+ 0.14
	5.31	5.22	- 0.09	5.43	5.40	- 0.03
	5.50	5.49	- 0.01	5.40	5.40	0
	5.38	5.41	+ 0.03	5.45	5.53	+ 0.08
	5.39	5.40	+ 0.01	5.42	5.49	+ 0.07
Average	5.43	5.44	+ 0.01	5.49	5.51	+ 0.02

(Differences are not mathematically significant.)

Mean O_2 uptake (μl/gm wet tissue) in 200 min.	121	123	-2	115	115	0
Range (μl/gm)	73-171	39-160		70-176	57-151	

(Differences are not mathematically significant)

Notes: i) pH at 24 hours post-mortem, minced undiluted samples, using a bench pH meter.

ii) Oxygen uptake measured by Standard Warburg technique at 37°C. (98.6°F.) 1 gm. minced tissue, 2 ml. isotonic saline, KOH as CO_2 absorber in the central cup, following the technique described by Hornsey (4)

The results in Table 1V confirm those of Table 111. There is no systematic significant difference in pH, nor in the residual ability to absorb oxygen in the l. dorsi between the left and right sides of

one animal. Neither is there any bias towards the sides corresponding to the shackled leg. It should be made clear, however, that there may be unexplained differences, occasionally as great as 0.5 pH units, between the l dorsi muscles from the sides of one hog. This is rather important when considering the processing results of experiments involving one or two pigs only.

The average figures for pH in Table 111 (5.7 - 5.8) are higher than those in Table 1V (5.4 - 5.5). Although the hogs examined were the same breed, housed and fed under standard conditions, those taken for Table 111 were slaughtered in May-July and those taken for Table 1V in September-November. This significant difference ($p < 0.001$) tends to confirm a seasonal variation in pigs, long known in the Wiltshire Curing Industry. It also offers corroborative evidence in agreement with Forrest et al (5) who indicated a greater incidence of pale, soft, watery hams in the American autumn. It is interesting to conjecture whether the low ultimate pH values result as much from the effects of higher environmental temperatures during the growing life of the pig as from adverse pre- and post-mortem treatment of the animal.

The ability of the back muscles of the pig to convert to high quality bacon in the presence of curing salts depends largely on the effects of post-mortem treatment and breed characteristic. Whenever the muscle pH falls rapidly post-mortem, the resulting bacon is liable to show a dulled cured colour. This is most likely to be due to the pH-induced instability of the proteins of the muscles leading to alteration during curing. Since the conversion of the natural meat pigment to the desired cured meat colour is dependent on residual reducing capacity in the muscle, the oxygen uptake and its relation to muscle pH at the time of cure is an important factor.

5. The variation of oxygen uptake with the pH of the musculus l. dorsi from heavy hogs.

From the work of which Table 1V is a summary there is a relationship between oxygen uptake and pH which confirms Hornsey's general findings (4). A higher meat pH gives rise to a greater oxygen uptake. Oxygen consumption by the l. dorsi determined in the Warburg apparatus follows the time curve described by Hornsey.

Figure 1 shows the plot of 86 individual pH/oxygen uptake figures. Those of oxygen used are the quantities of gas (in μl/gm wet tissue) taken up in the 60 minutes between 140 and 200 minutes after the start of the estimations. This particular portion of the respiration/time curve is linear. The correlation co-efficient of the regression line in Fig. 1 is r = +0.7 which is highly significant($p < 0.001$). The variation will be seen to be quite large suggesting that factors other than pH alone are playing a part.

From an economic point of view an attribute of lean meat that is important in manufacturing processes is its ability to retain its own moisture, and that which may be added to it, under storage and cooking conditions. Water holding capacity of lean meats has been the subject of much work in various countries. The work of Grau and Hamm in 1953 (6) laying the basis of a simple test for the determination of WHC has paved the way for greater understanding of many of the practical troubles assailing the meat manufacturer.

6. The variation of water holding capacity with pH of the m.l. dorsi of heavy hogs.

A modification of the original Grau and Hamm "press" technique for measuring the WHC of lean meat provides for application of a fixed and known pressure to comparable weights of minced tissue for a fixed time. The procedure outlined in the Appendix uses sample weight differences rather than exudate areas for the determination of bound water. This tends to eliminate errors in area measurements and uncertainty associated with that area under the squeezed meat disc. Perspex (Plexiglas) has been rejected from the apparatus on the grounds of flexibility and hence non-uniform pressure application. Perspex is also a good heat insulator and there is circumstantial evidence of the energy of compression, converted to heat, denaturing protein and affecting filter paper diffusion characteristics. The apparatus is of an all metal construction, the main pressure plates being thick steel milled flat.

Fig. 2 is a plot of the WHC of the l. dorsi muscle at its mid-point against the pH 24 hours post-mortem. The WHC is defined as the

bound water associated with the moisture free muscle residue as a percentage. The correlation coefficient of the regression line is $r = +0.85$ which mathematically is highly significant ($p < 0.001$)

Discussion.

The experimental work described indicates that the British "heavy" hog shows similar variation of characteristics expected of different breeds of pig, handled on a normal slaughter line. However, some of the variability should be evened out by judicious interbreeding of stock. In this way the suggested hereditary defects attributed to extensive inbreeding of one strain could be avoided. Pale exudative lean meat should be minimised with a hybrid pig, especially with Large White strain in its lineage.

It is also possible that the feeding regime for pigs could be modified to reduce quality defects. It will be noted from Table 1 that the feeding programme for Lot B has provided hogs that are apparently less susceptible to high temperature/rapid pH fall effects than those of Lot C which were fed a swill diet. This inference does not, in any way, reduce the need for rapid chilling immediately post-mortem.

From all aspects studied, a minimum pH of 5.6 (up to 24 hours post-mortem) in the l. dorsi should be aimed for. This should be achieved by balanced breeding and feeding, and by good pre- and post-slaughter practice.

Conclusions.

1. Differences in the rates of temperature fall of hog carcases in slaughter line chillrooms can affect the quality of the meat for processing.

2. More rapid chilling rates improved the yield of hams in our experiments.

3. Although unexplained pH differences between the two l. dorsi muscles of individual carcases do occasionally occur, there is no mathematical significance attributable to these differences over a sufficient number of pigs.

4. The pH of the l. dorsi muscle from the side of a carcase corresponding to the shackled leg does not differ from that of the other side.

5. There is a seasonal difference in pH of the l. dorsi muscles from pigs of the same breed.

6. The findings of Hornsey, that oxygen uptake of the l. dorsi muscle from different animals increases with increasing ultimate pH, are confirmed.

7. The water holding capacity of the l. dorsi muscle of different pigs increases with increasing ultimate pH.

APPENDIX.

Method for determination of Water Holding Capacity of Pork.

Introduction.

In the original method of Grau and Hamm (6) small portions of lean meat were squeezed between Plexiglas plates. A filter paper between the meat and one Plexiglas plate absorbed the exudate. The area of the exudate stain on the filter paper was shown to have an inverse relationship with the water holding capacity of unit weight of the meat.

Definition.

In this paper we define the water holding capacity of the meat as that water which cannot be squeezed out of the meat sample, under our test conditions, expressed as a percentage of the moisture-free meat residue.

Modification of the original method.

Wierbicki and Deatherage (7) controlled the pressure applied to their meat by means of an hydraulic ram operated at a gauge reading of 500 lb./in^2 (35 Kgm/cm^2) for a squeeze period of one minute.

Wismer-Pedersen (8) used a sample weight difference measurement before and after squeezing rather than an exudate area measurement on the filter paper.

We have used the principles of these modifications and introduce others:

1) We have found evidence of protein alterations as a result of squeezing samples between Perspex plates. This showed up as reduced solubility of proteins on the filter paper. Clogging of the filter paper with precipitated protein will alter the water flow characteristics and introduce errors where area measurements are concerned. The possibility of coincidental alteration of the protein of the meat residue prompted elimination of Perspex from the apparatus. Some of the energy of compression will be converted to heat and the heat insulation properties of Perspex would localise this heat in the meat.

2) We have confirmed the conclusions of Wierbicki and Deatherage and find an inflection in the curve of WHC against applied pressure. In our apparatus the force applied per unit area of meat disc is 369 lb./in.^{2} (26 Kgm/cm^2) and the duration of squeeze is one minute for a sample weight of 200mgm.

3) We have replaced the time-consuming area measurement with an estimation of WHC based on sample weight differences. This requires complete removal of the filter paper from the meat disc which adheres to the aluminium plate. To facilitate this we introduce a fine nylon filament mesh between the filter paper and the meat sample. The amount of water

retained by this mesh is small in comparison with that remaining in the squeezed meat. The mesh adheres to the meat and is included in the weight of the aluminium plate for calculation purposes.

4) Our calculation uses the actual weight of water in the squeezed meat, which we determine by infra-red heating for 15 minutes, weighing before and after. The moisture-free meat residue estimation is made on a separate sample dried by infra-red heating. In this way we eliminate any error due to dissolved solids left on the filter paper.

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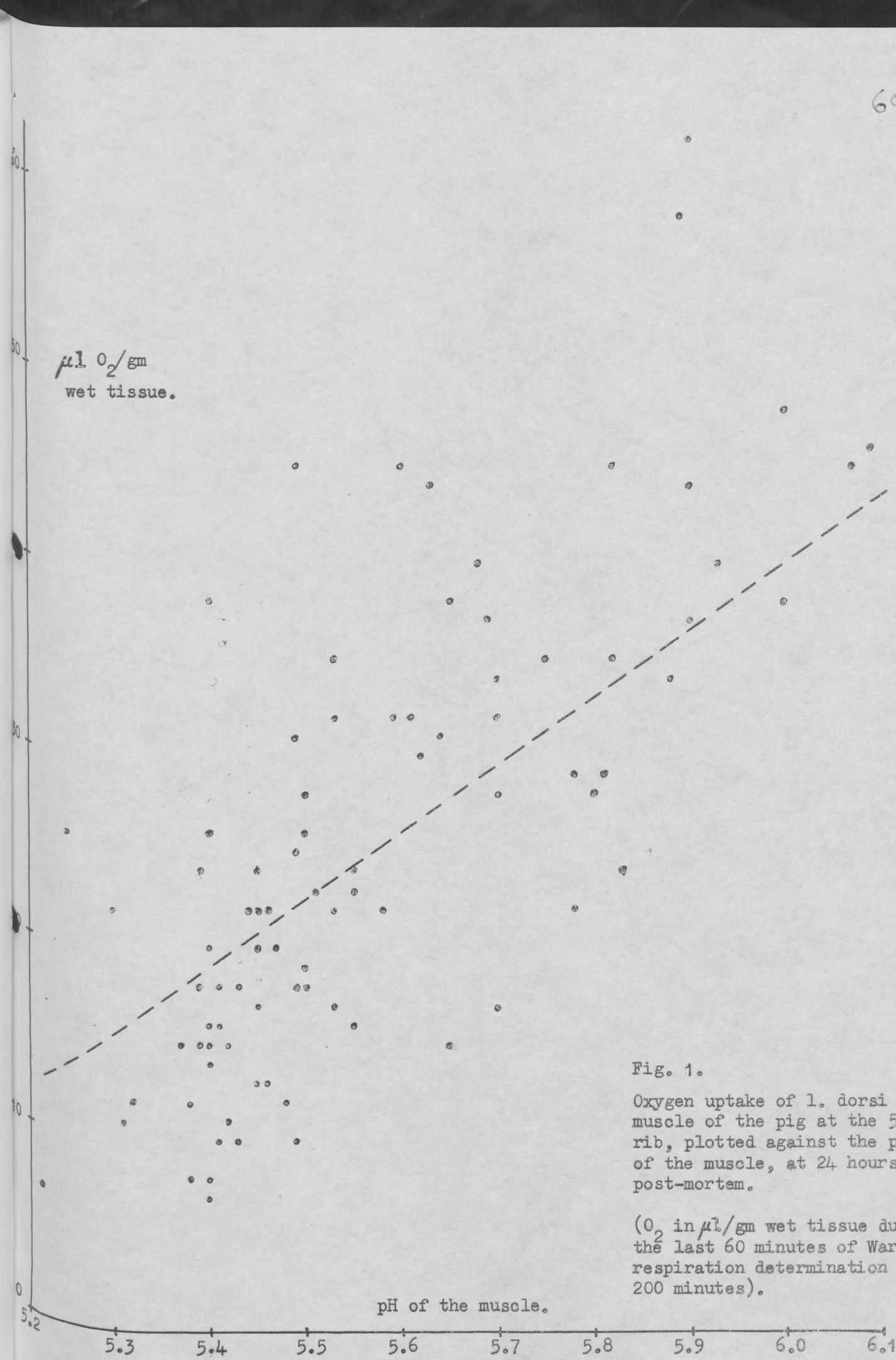

Fig. 1.

Oxygen uptake of l. dorsi muscle of the pig at the 5th rib, plotted against the pH of the muscle, at 24 hours post-mortem.

(O_2 in μl/gm wet tissue during the last 60 minutes of Warburg respiration determination of 200 minutes).

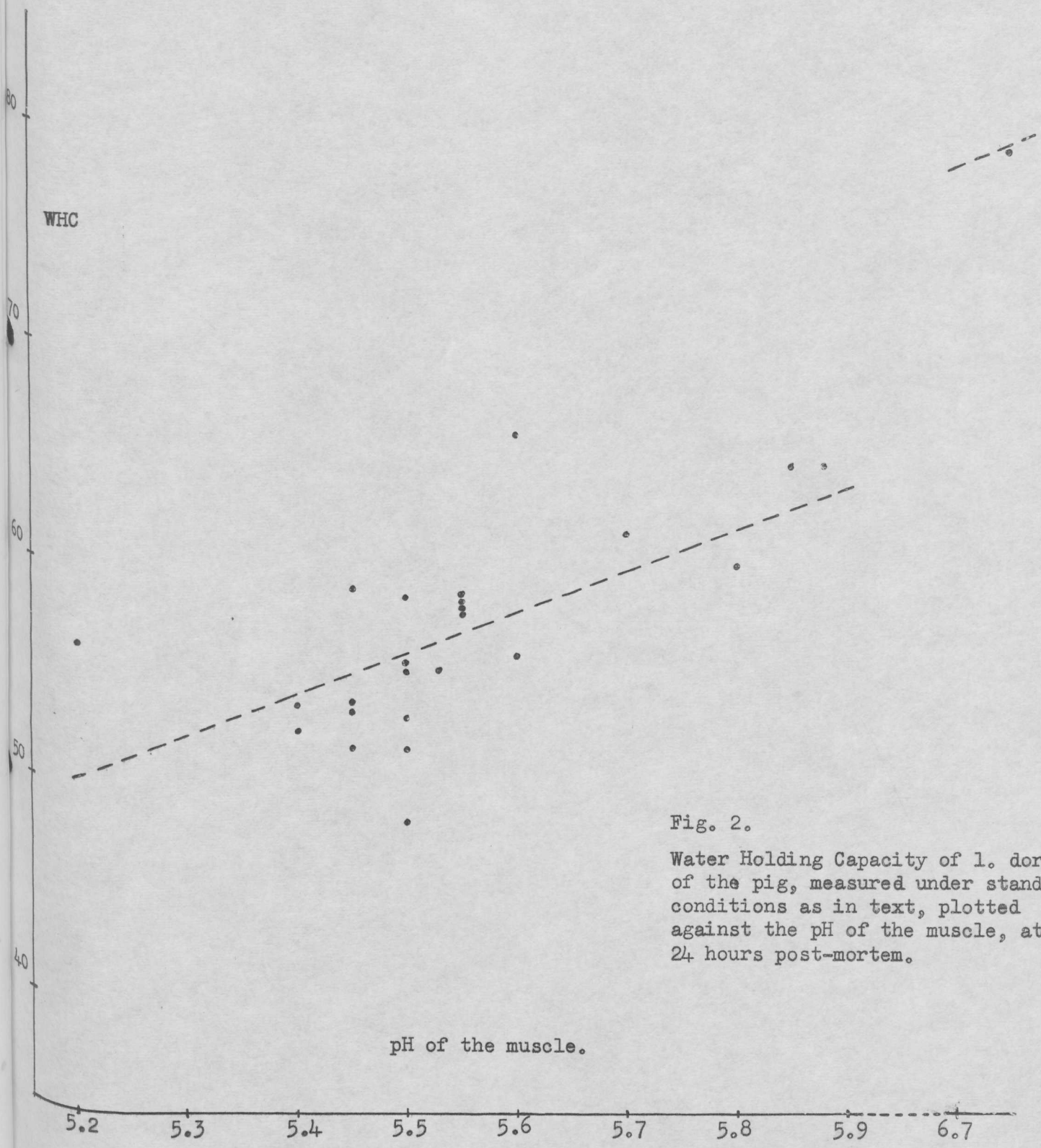

Fig. 2.

Water Holding Capacity of l. dorsi of the pig, measured under standard conditions as in text, plotted against the pH of the muscle, at 24 hours post-mortem.

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ABSTRACTS

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ABSTRACT

Traditionally, the U.K.pig industry has been supplied with two kinds of pig, one being of closely controlled characteristics for cured meat manufacture and the other with little or no control for manufacture of comminuted meat products. In recent years the "heavy hog" has been developed to serve both sides of the industry simultaneously. Its greater size and depth of fat has necessitated closer control of the pre- and post-slaughter environment to minimise variation in the meat. We have attempted to assess the variation obtained, to relate it to variations in processing conditions, and to discover advantages which could be gained by improved handling of carcases.

Differences of post-mortem chilling rate can be encountered under commercial conditions, carcases entering an empty, cold chillroom cooling initially more rapidly than those entering a full, warmer chillroom. These differences are reflected in a lower rate of pH fall post-mortem in the more rapidly chilled carcases. These pH differences were not always reflected in lean meat colour scores, and it would appear that other factors also play an important part in determining lean meat quality.

Drastically increasing the chilling rate by immersion of sides in ice produced an improved yield of cooked ham.

A surprisingly large variation in properties was found between the left and right sides of some animals, although the cause of the variation could not be established. Substantial differences were found both in ultimate pH and in respiration of the muscle tissue, but the differences were not systematic to the sides, nor were they connected with the more stressed side by which the animal was shackled. The respiration studies confirmed Hornsey's findings that respiration increased with increasing pH.

The variation in ultimate pH corresponds with a variation in water-holding capacity, determined by a modification of the method of Grau and Hamm. The relationship is highly rectilinear.

Notes sur les "Heavy Hogs" (gros porcs) britanniques manipulés dans une chaine d'abattage d'usine.

D.J. Locke et R. Vetterlein.

EXTRAIT.

L'industrie porcine du Royaume-Uni disposait traditionnellement de deux types de porc, l'un d'eux, dont les caractéristiques étroitement contrôlées, était utilisé pour la production de viande salée et l'autre, dont le contrôle minime ou inexistant, servait à la production de produits de viande broyée. Le "Heavy Hog" a récemment été développé en vue de desservir simultanément les deux aspects de l'industrie. Il a été nécessaire, du fait de sa stature plus grande et de l'épaisseur plus grande due lard, d'effectuer un contrôle plus strict des conditions ambiantes avant et après l'abattage afin de minimiser les variations de la viande. Nous avons essayé de déterminer le degré de variation obtenu, d'établir le rapport entre cette variation et les conditions de transformation et de découvrir les avantages qu'il pourrait y avoir à améliorer le maniement des carcasses.

Des différences dans la vitesse du refroidissement post-mortem peuvent se produire dans des conditions commerciales car les carcasses introduites dans une chambre frigorifique froide et vide se refroidissent initialement plus vite que celles qui sont introduites dans une chambre pleine et à température plus élevée. Ces différences se traduisent par une valeur de chute du pH post-mortem moins élevée dans la cas de carcasses qui ont été refroidies plus rapidement. Ces différences du pH ne s'exprimaient pas toujours dans l'évaluation de la couleur de la viande maigre et il semblerait que d'autres facteurs jouent également un rôle important en ce qui concerne la qualité de la viande maigre.

Une augmentation considérable de la vitesse de refroidissement réalisée en immergeant les demi-carcasses dans de la glace a permis d'améliorer le rendement de jambon cuit.

On a enregistré de surprenantes différences des propriétés entre les côtés droits et gauches de certains animaux, mais la cause n'en a pu être établie. On a trouvé des différences considérables à la fois dans le pH ultime et dans la respiration du tissu musculaire, mais les différences ne s'en tenaient pas systématiquement à l'un ou l'autre des côtés et elles n'avaient pas non plus de rapport avec le côté par lequel on avait enchaîné l'animal assommé. Les études sur la respiration ont confirmé les résultats obtenus par Hornsey selon lesquels la respiration augmente en même temps que le pH.

La variation du pH ultime correspond à une variation du pouvoir de rétention d'eau, déterminé en se basant sur une modification de la méthode de Grau et Hamm. Le rapport est fortement rectiligne.

Bemerkungen über die Behandlung englischer "Heavy Hogs" (schwere Schweine) in gewerblichen Schlachtereien

D.J. Locke und R. Vetterlein.

ZUSAMMENFASSUNG.

In der Vergangenheit ist die englische Schweinefleischindustrie mit zwei Arten Schweinefleisch beliefert worden: die eine mit streng kontrollierten Eigenschaften zur Herstellung von gepökeltem Fleisch und die andere nur wenig oder sogar überhaupt nicht kontrolliert zur Herstellung von aus zerkleinertem Fleisch hergestellten Fleischwaren. In den letzten Jahren ist das "Heavy Hog" dementsprechend gezüchtet worden, um gleichzeitig die Bedürfnisse beider Industriesparten zu befriedigen. Da das Schwein grösser ist und eine dickere Fettschicht hat, ist eine strengere Umweltkontrolle vor sowie nach der Schlachtung erforderlich, um Unterschiede in der Fleischbeschaffenheit möglichst gering zu halten. Wir haben versucht, die sich ergebenden Unterschiede festzustellen und eine Beziehung zu den Unterschieden in der Fleischverarbeitung herzustellen. Wir haben ebenfalls versucht herauszufinden, welche Vorteile eine Verbesserung in der Behandlung von Karkassen mit sich bringen würde.

Unter handelsüblichen Bedingungen können Unterschiede in der postmortalen Abkühlungsgeschwindigkeit vorkommen; Karhassen, die in einen leeren, kalten Abkühlraum kommen, kühlen anfänglich schneller ab als Karkassen, die in einen vollen, wärmeren Abkühlraum kommen. Bei den schneller abgekühlten Karkassen spiegeln sich diese Unterschiede in einer niedrigeren Geschwindigkeit des postmortalen pH-Wert-Abfalles wider. Diese Unterschiede im pH-Wert spiegelten sich jedoch nicht immer in den Farbwerten für mageres Fleisch wider und es ist anzunehmen, dass die Qualität von magerem Fleisch weitgehend von anderen Eigenschaften abhängig ist.

Eine drastische Erhöhung der Abkühlgeschwindigkeit durch Eintauchen der Seiten in Eis hatte einen besseren Ertrag an gekochtem Schinken zur Folge.

Es wurde in einigen Tieren ein erstaunlich grosser Unterschied zwischen den Eigenschaften der rechten und der linken Seite festgestellt, obwohl die Ursache dieses Unterschiedes nicht ermittelt werden konnte.

Erhebliche Unterschiede in den End-pH-Werten und in der Respiration des Muskelfleisches wurden festgestellt; diese Unterschiede bezogen sich jedoch nicht systematisch auf eine bestimmte Seite und hängten auch nicht davon ab, welche Seite mehr erregt wurde infolge der Fesselung des betäubten Tieres. Die Respirationsuntersuchungen bestätigten Hornseys Feststellungen, dass mit zunehmender Respiration der pH-Wert ebenfalls ansteigt.

Die Schwankung im End-pH-Wert entspricht einer Schwankung im Wasserhaltungsvermögen, welches unter Anwendung einer Abänderung der Methode von Grau und Hamm festgestellt wurde. Diese Beziehung ist äusserst gradlinig.