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The effect of some pre-slaughter variables on pH changes post-mortem in pork, and the use of pH in predicting lean meat quality factors.

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THE EFFECT OF SOME PRE-SLAUGHTER VARIABLES ON pH CHANGES POST-MORTEM IN PORK, AND THE USE OF pH IN PREDICTING LEAN MEAT QUALITY FACTORS.

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The British heavy hog (1) has been developed to provide a single standardised source of raw material for both cured and comminuted products. The dressed carcase weighs 210 lbs (95 Kg.), as against the 150-160 lbs (70 kg.), of the baconer.

A widespread literature has grown up in recent years on the effect of variation in the rate of post-mortem pH fall on lean meat quality (2, 3, 4, 5) and it was decided to investigate the application of this work to our own processing techniques. The bulkier carcase, cooling more slowly, might be expected to give as a result poorer or more variable lean meat quality, which would be reflected in product quality and which must therefore be minimised.

To this end we have initiated a twelve-month study on pigs of known ancestry and management, and on a constant feeding regime, in an attempt to discover which factors in the management of the live pig to the moment of slaughter affect the pattern of post-mortem pH change, and to connect post-mortem pH change with variation in quality of both lean meat and products. The present paper covers the first six months of the survey.

The pigs under investigation come from our demonstration farm at Kington Magna, Dorset, about 100 miles (160 Km.) from the factory. They are principally from Wessex sows, sired either by a Landrace or one of two Large White boars. The ear-number given to the pig at birth serves to identify breed, and the slapmark given on despatch to the factory is used to identify its housing history. The feeding regime is a supplemented cereal meal with whey. The pigs are collected at about 07.00 hours by a regular haulier, and when possible segregated from loads collected from other farms. They arrive at about 13.00 hours and are rested overnight, being slaughtered on the following morning. The ease or otherwise of the loading operation is recorded by the farm, while we ourselves observe the unloading and slaughtering operation.

The resistance to movement of the shoulder is observed 30 minutes after slaughter as a qualitative measure of the state of rigidity of the carcase. pH is recorded 45 and 120 minutes after slaughter. The instrument used is an E.I.L. portable pH meter, model 30B, with a spear probe (SDSA). The measurements are taken in the left l. dorsi at the fifth rib, entrance for the probe being made with a surgical scalpel. On the following morning, a sample is taken from the left l. dorsi at the fifth rib and pH is again recorded. We refer to the three pH measurements taken as pH_{45}, pH_{120} and $pH_{ult.}$ respectively. The colour of the lean meat is assessed on a seven-point scale, pale muscles receiving high scores and well-coloured muscles low scores, and note is made of the exudative samples. Water-soluble protein is determined on a 1 : 1 aqueous extract of the minced l. dorsi by a micro-Kjeldahl method and the water-holding capacity is determined by the method previously described (6). Each week two carcases are selected with a high pH and two with a low pH pattern and these are subjected to separate product evaluation. (7).

RESULTS.

1. Effect of breed and pre-slaughter management on post-mortem pH and quality characteristics.

Overall pH distribution.

The overall pH distributions for the pigs so far covered (about 500) are shown in Fig. 1. The picture in each case resembles that shown by a random selection of pigs from our normal intake. The pH_{45} distribution shows no major features, and few of the pigs have a pH_{45} below 5.8. We have found a correspondingly low incidence of the extremely pale, coarse and watery condition often known as 'white muscle'. The pH_{120} distribution shows a tendency to two peaks, at about 6.0 and 5.6. This tendency has been more noticeable in our normal intake.

Effect of breed on pH distribution and lean meat colour.

Roughly equal proportions of Landrace-sired and Large White-sired progeny have been examined. Table 1 gives the mean pH and standard deviations and Fig. 2 shows the distributions.

Table 1. - Mean post-mortem pH figures for Landrace-and Large White-sired progeny.

	Landrace sire	Large White sire
No. of pigs	141	125
pH_{45}	6.22	6.18
SD.	± 0.22	± 0.28
pH_{120}	5.98	5.84
SD	± 0.25	± 0.27
pH_{ult}	5.69	5.56
SD	± 0.22	+ 0.20

Two points of interest emerge. Landrace-sired progeny show higher average pH_{120} and pH_{ult}, significant at the 1% level. Also, the acid pH_{120} peak in the distribution of the Large White-sired progeny is not observable in the pH_{120} distribution of Landrace progeny.

A corresponding difference was observed in lean meat colour:

	Landrace sire	Large White sire.
Lean meat colour	4.26	4.68
SD	± 1.16	± 1.20

The difference is significant at the 5% level.

The results given above do not take into account variations in breed of sow. In fact, pure Wessex sows have been principally used with the Landrace boar, while the Large White boars have served an appreciable proportion (25%) of cross-bred sows. The significance of the results is not altered if results from cross-bred sows are removed.

We do not as yet possess sufficient data to evaluate any effect attributable to sow breed.

Effect of housing.

Four major housing techniques are used on the farm:

(a) Open yard
(b) Sweathouse
(c) Dutch barn
(d) Intensive house.

Table 2. - pH means and colour scores for pigs from different houses.

	Open yard	Sweathouse	Dutch barn	Intensive house.
No. of pigs	41	68	163	150
pH_{45}	6.16	6.26	6.17	6.17
pH_{120}	5.86	5.86	5.92	5.90
pH_{ult}	5.62	5.62	5.70	5.64
Lean meat colour	4.65	4.81	4.11	4.63

The Dutch barn appears to give a higher pH_{120} and pH_{ult} (significant at the 5% level) and a deeper lean meat colour (significant at the 0.1% level). However, this regime has had a higher percentage throughput of Landrace progeny. When these figures are compared with the calculated figures for the Landrace/ Large White ratios that were found in practice, the two sets of data are closely comparable, and no significant difference then exists.

However, by the same criterion, the lean meat colour for pigs kept in the sweathouse is then significantly paler than expected, despite the similarity in pH_{120} and high pH_{45}.

Pre-slaughter stresses.

The pigs so far received have experienced weather conditions varying from the extreme heat of summer to winter conditions. To show variations attributable to season they have been divided into three categories:

Table 3. - Seasonal variation in mean pH

	Aug-Sept.	Oct-Dec.	Jan-Feb.
pH_{45}	6.16	6.20	6.21
pH_{120}	5.94	5.91	5.86
pH_{ult}	5.71	5.65	5.59

The ultimate pH has fallen with the mean ambient temperature, although statistical significance cannot be given to the differences.

Batches reported as 'difficult to load' have shown higher pH_{ult}, the average being 5.76 over five batches, although pH_{120} and pH_{45} distributions were not affected. One batch, recently received and not included in Table 3, which proved exceptionally difficult, both to load and to unload, had mean pH_{45} 6.41, mean pH_{120} 6.10, and mean pH_{ult} 6.02. In general the unloading operation takes only a few minutes, as against up to an hour for loading difficult batches. The contribution of this factor to the overall pre-slaughter stress should therefore be small under normal circumstances.

Stress during slaughter.

Before slaughter, the animals are driven from their lairage to a holding pen, from which a narrow passageway, wide enough for one pig, leads to the stunning area. While the holding pen is full, animals enter the passage freely, but as it empties and the pigs have freer movement, they are often actively reluctant to enter the passage. Observing the consequent excitement prompted us to separate the data into two categories representing first and last slaughtered animals. The results are shown in Fig. 3. The point of interest here is the marked double pH_{120} peak in the last slaughtered animals, which is absent in those first in the killing order.

The figures on one particular batch which were unusually excited during the slaughtering operation are also of interest. The mean pH_{45} (28 pigs) was 6.02, the lowest we have recorded, and a third of the batch had $pH_{120} < 5.7$. One carcase showed fairly typical 'white muscle'. (pH_{45} 5.7, pH_{120} 5.4, pH_{ult} 5.35)

Post-mortem rigidity.

The resistance to movement of the left shoulder was observed and categorised at the end of the dressing line, some 30 minutes after slaughter.

Table 4. - Mean pH and colour scores for pigs showing marked rigidity 30 minutes after slaughter.

	pH_{45}	pH_{120}	pH_{ult}	Lean meat colour.
Mean	6.04	5.85	5.70	4.39
SD	± 0.24	± 0.27	± 0.26	± 1.54

The lower pH_{45} and higher pH_{ult} show that these carcases were nearing the end of post-mortem glycolysis. The variance of lean meat colour was significantly ($P < 5\%$) greater than that of the normal population. Carcases with low pH_{45} and low pH_{ult} showed pale muscle colour and were frequently exudative, while carcases with high pH_{45} and pH_{ult} were usually of a deep colour, firm and dry. This test appears to separate from the general population a selection with greater overall variability.

2. The relationship between post-mortem pH and some lean meat quality factors.

Lean meat colour.

The lean meat colour evaluation consists of a simple, numerical score based on the scale:

1. Dark muscle
2. Deep red
3. Red, translucent
4. Pink, (average l. dorsi.)
5. Pale pink, slightly opaque.
6. Very pale pink, opaque.
7. Grey-white, coarse, opaque (white muscle.)

The correlation coefficients of pH with lean meat colour evaluated on this scale were:

pH_{45}	pH_{120}	pH_{ult}
-0.208	-0.358***	-0.372***

Thus pH_{120} gives us better indication of lean meat colour than pH_{45}, and is almost as good as the ultimate muscle pH.

Exudative meat.

Lean meat samples were taken from the carcases at the fifth rib 24 hours after death and were wrapped individually in imitation parchment paper. After 45 minutes, a proportion were found to have exuded free fluid. The pH_{45} of these carcases was not demonstrably different from that of the normal population, but the vast majority had $pH_{120} < 5.8$. The lean meat colour was often, but by no means always, paler than normal Here again, the pH_{120} measurement gave us clearer indication of meat quality than pH_{45}.

In Large White-sired carcases, the mean pH_{120} for exudative samples was 5.52 (23 samples), no sample having pH_{120} above 5.7. For Landrace-sired carcases the mean pH_{120} was 5.69 (31 samples). This difference was significant at the 0.1% level. However, no difference in either lean meat colour or soluble protein was distinguishable between the lots.

Water-soluble protein and water-holding capacity.

Water-soluble protein and water-holding capacity were determined for all carcases undergoing product evaluation. In these samples the water-soluble protein readings correlated significantly with all three pH readings, the coefficient increasing from pH_{45} to pH_{ult} (Table 5).

The water-holding capacities show an unexpected pattern, and have given poorer correlation with pH_{ult} than we would have expected from earlier work in our Laboratory (6). We are continuing with this work, and in addition we are determining water-binding capacity by a simplification of Hellendoorn's method (8).

Table 5. - Correlation of water-holding capacity and water-soluble protein with pH.

	pH_{45}	pH_{120}	pH_{ult}
WHC	0.414**	0.301*	0.273
Sol. protein	0.494***	0.516***	0.559***

DISCUSSION.

1. General pH distribution.

The general pH_{45} pattern does not show the widely spread double peak that has been reported in Danish pigs, but evidence of a second peak at pH 5.6 can be seen in the pH_{120} curve, and is a regular feature of the pH_{120} pattern of our normal intake. We do not believe this to be evidence of two populations within our pigs, but merely the accumulation of the carcases showing more rapid glycolysis at the point where acid production has almost ended. The time of occurrence of a peak caused by this mechanism will depend on the rate of glycolysis occurring in the more rapidly changing carcases, and in part on the level of lactic acid present in the tissue at death, and its size will depend on the proportion of such animals in the general population. The importance of such a peak as a criterion of overall meat quality will depend on muscle temperature and cooling rate at the time of its appearance.

2. Breed.

Post-mortem glycolysis in Large White muscle is considered to proceed more slowly than in Landrace muscle(5), and on these grounds we would have expected that the majority of pigs in the acid peak of the pH_{120} distribution to have come from the Landrace boar. In fact the opposite tendency was found.

The significantly higher average pH_{ult} of the Landrace-sired pigs indicates some degree of exhaustion of muscle glycogen reserves. Presumably the more excitable Landrace animal is stressed to a greater extent than the Large White by the operations of loading, transport and lairage. It has been noticeable that whenever pre-slaughter stress has been severe, the result has been an elevated pH_{ult}, with the other pH readings being also affected when muscle glycogen depletion has been particularly marked. The rather unexpected pH distribution can therefore be connected with muscle glycogen depletion.

The pigs for which full breed data are available were killed almost entirely during the colder months. At this time we can consider the consequences of the breed-transport interaction to be generally advantageous, both from the point of product colour and presumably of product yields. However, further elevation of pH_{ult} values might be expected during hot weather, giving the possibility of reduced shelf life.

3. Housing.

There would appear to be no major differences in pH which can be attributed to the Dutch barn, the intensive house, the open yard or the sweathouse.

The sweathouse received a higher percentage of Landrace progeny than the general population and showed a somewhat higher pH_{45}, but despite this the lean meat colour was significantly paler than that expected for its Landrace/Large White ratio. This may be a reflection of the lower demand for energy production in the warm and confined environment.

4. Stress due to loading and transport.

Despite the differences in pH_{ult} found between loads more highly stressed by environmental temperature or excitement during loading, little or no difference could be seen in pH_{45} or pH_{120} distribution. Thus such stresses may be considered to be counteracted by the resting period as far as any possible effect in reducing lean meat quality is concerned. They will therefore be of importance only in so far as they deplete muscle glycogen reserves and reduce liver yields.

5. Stress during slaughter.

At present we possess only qualitative evidence, but it leads to a connection between increased excitement at the time of slaughter and low pH soon after death. Such excitement may therefore be expected to produce meat of poorer quality for processing, and to reduce overall yields.

6. pH and lean meat quality factors.

The small number of pigs showing low pH_{45} agrees well with the observed rarity of cases of 'white muscle' in our own operations. It also shows that pH_{45} will be of far less value to us for predicting quality than it has proved to be in other countries.

The more acid pH_{120} peak covers some 15% of pigs in the present survey. At this stage muscle temperatures in our pigs are usually between 29° and 33°C. at a depth of 2" (5cm.) at the site of the pH readings and even higher where the muscle bulk is greater. It is therefore conceivable that a low pH at this stage will have some effect in reducing meat quality.

This would appear to be borne out by our observations. A deeper lean meat colour is significantly associated with a high pH_{120}, but is not significantly correlated with pH_{45}. Also, meat which readily exudes fluid is generally associated with a pH_{120} below 5.8, but cannot be reliably predicted by pH_{45}. On the other hand, water-binding capacity as determined by the press method is most closely associated with pH_{45}.

An extremely interesting facet is the marked difference in pH_{120} of exudative muscle from the two breeds, which was not accompanied by difference in soluble protein. In view of this, it would appear that the reason for the difference must lie either in the water-holding capacity of the proteins, or in the gross structure of the tissue, indicating that possibly the change from 'closed' to 'open' structure occurs at higher pH in the Landrace progeny.

Conclusions.

1. In our process, pH_{120} provides a more useful estimate of lean meat quality than pH_{45}.

2. No significant pH differences were observed that were attributable to difference in housing. Pigs kept in the sweathouse had paler lean meat colour.

3. Severe stress during the loading, transporting and lairaging operation can affect the ultimate pH of the lean meat. The Landrace-sired progeny in our survey were more susceptible to such stresses than Large White-sired progeny.

4. A seasonal variation in average ultimate pH is observable, pH_{ult} falling during cooler weather.

5. Stresses during the slaughtering operation lead to an increased number of carcases of low pH_{120}, and can produce 'white muscle'.

6. Carcases judged to show marked rigidity thirty minutes after slaughter had on average lower pH_{45} and higher pH_{ult} than the general population. The lean meat colour of such carcases showed significantly greater variability than the general population.

7. Lean meat colour was significantly correlated with pH_{120} and pH_{ult}. Water-soluble protein was highly significantly correlated with all pH readings. Water-holding capacity was highly correlated with pH_{45}, and significantly correlated with pH_{120}.

8. Carcases which yielded muscle samples showing visible exudation could not be separated from the general population on the basis of pH_{45}. They generally had a pH_{120} below 5.8.

9. A significantly lower pH_{120} was required to produce visibly exudative muscle in Large White-sired carcases than in Landrace-sired carcases.

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FIG. 1 OVERALL pH DISTRIBUTION

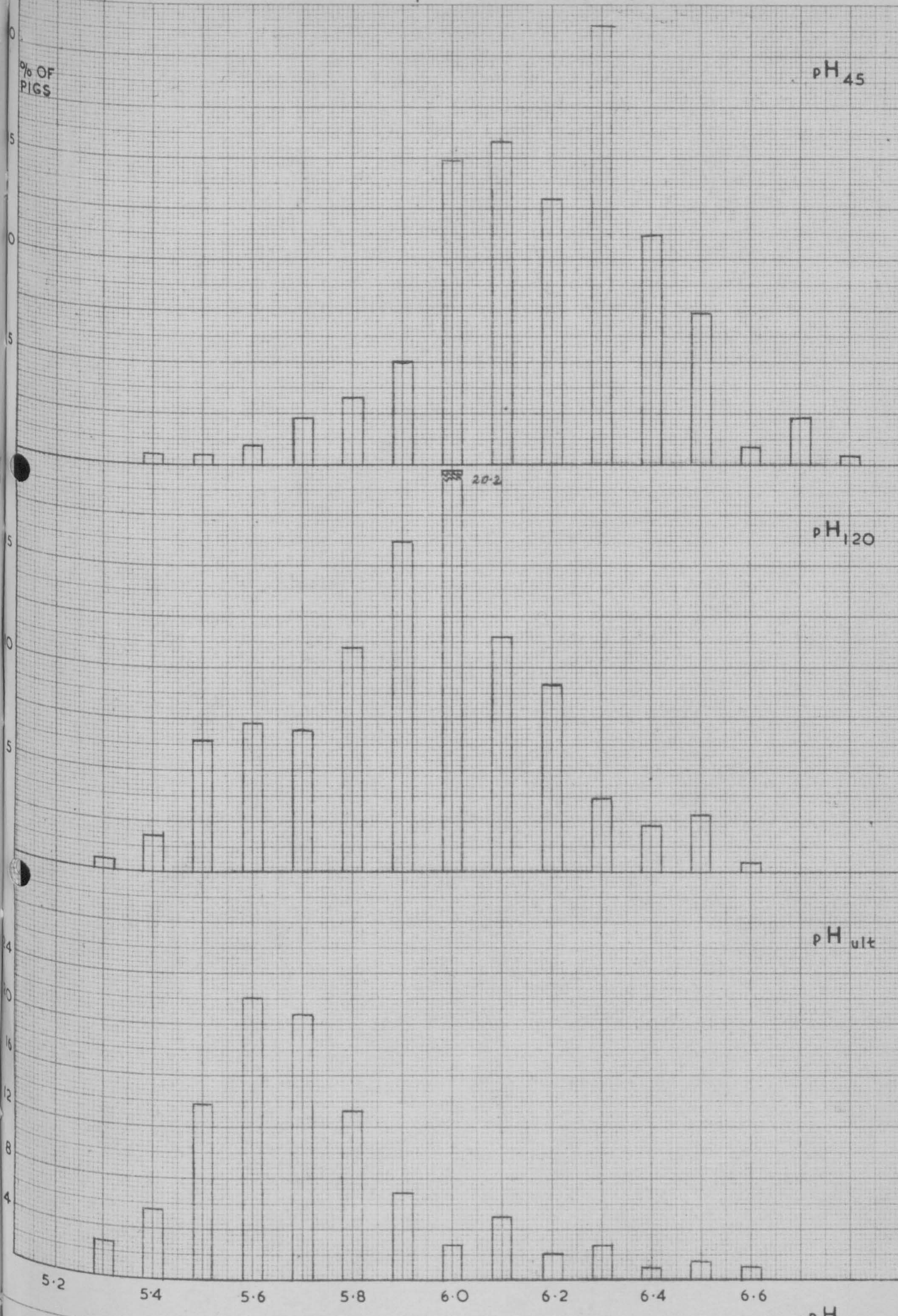


FIG. 3. pH DISTRIBUTION OF FIRST AND LAST SLAUGHTERED PIGS

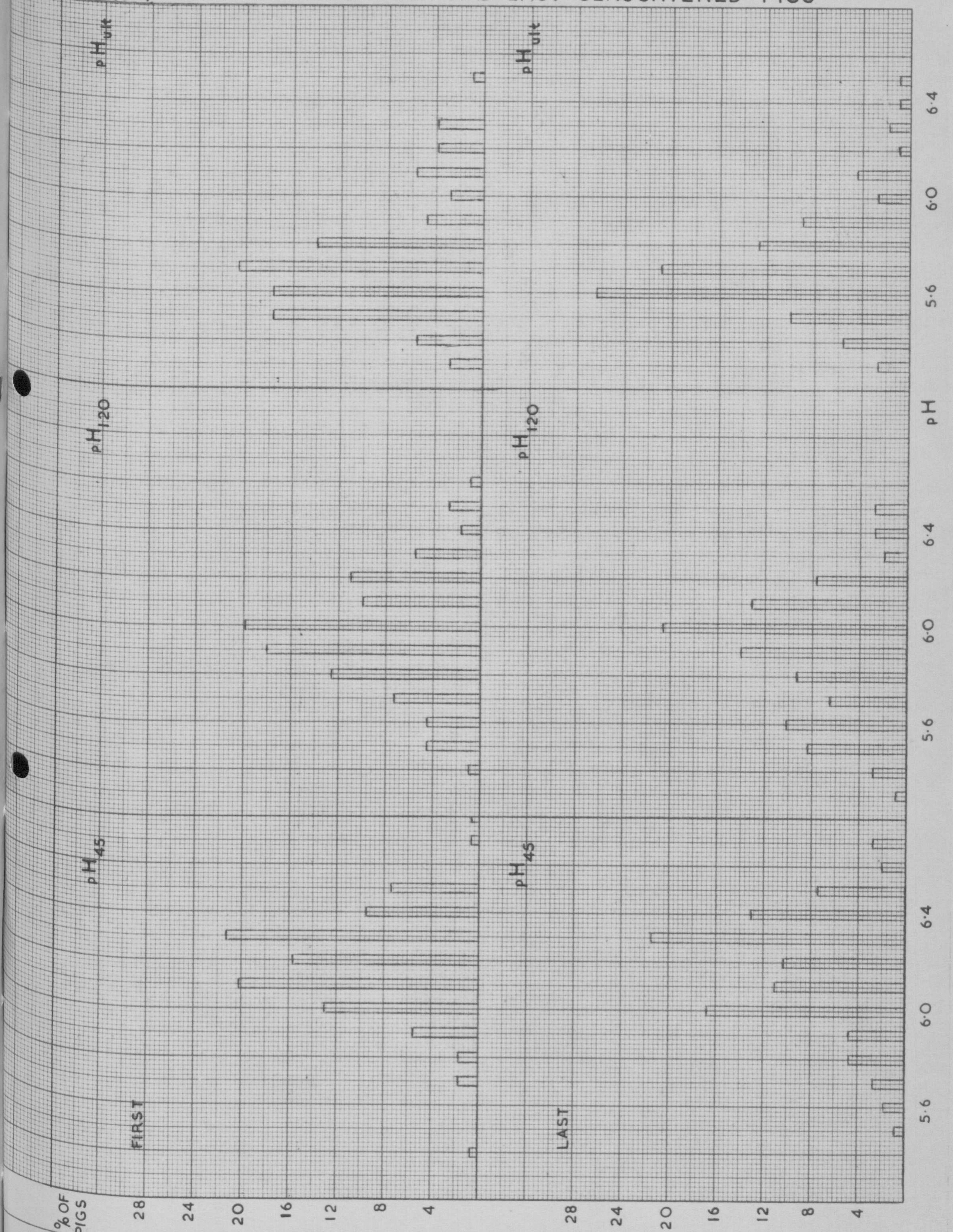
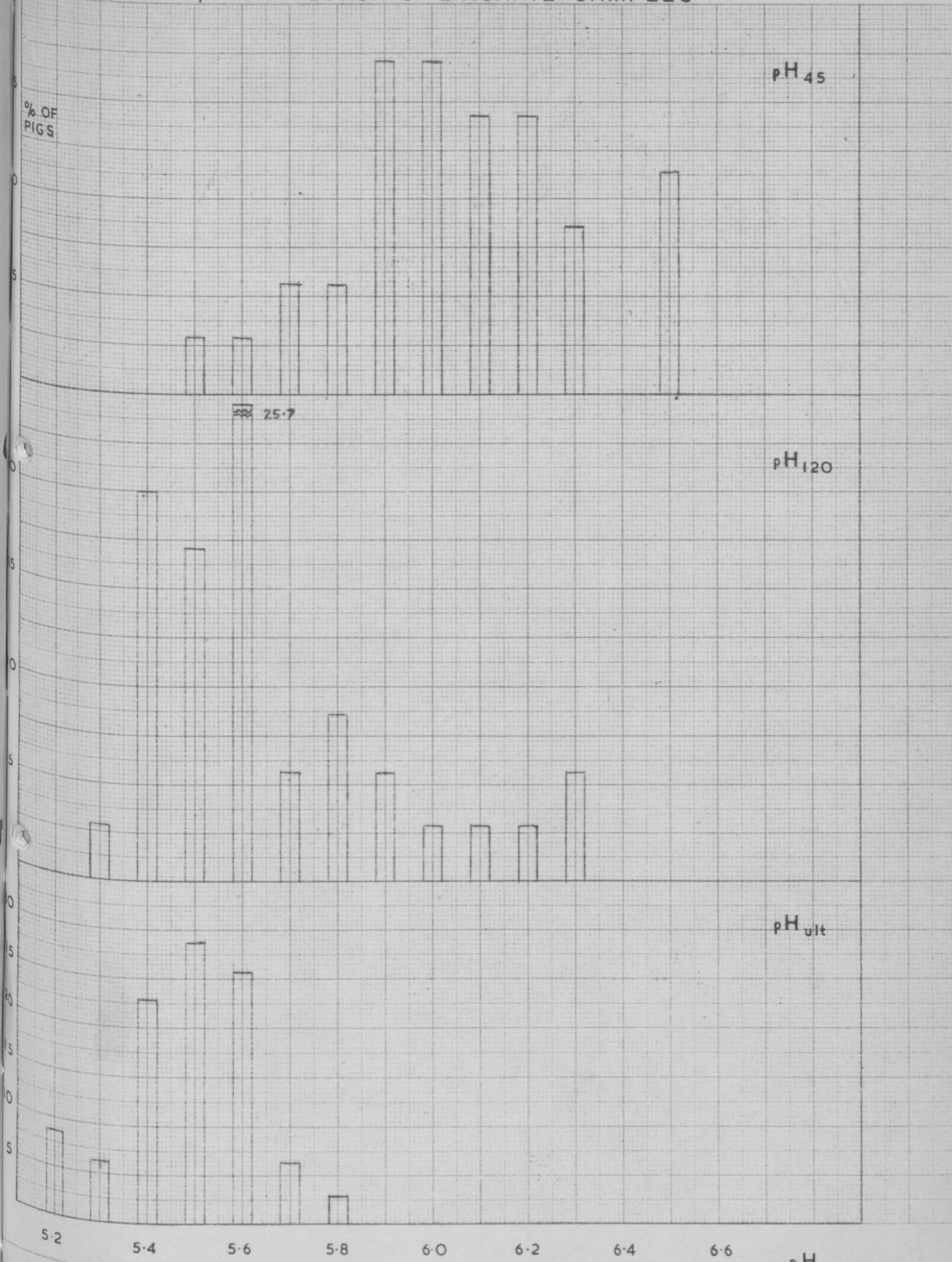


FIG. 4 pH DISTRIBUTION OF EXUDATIVE SAMPLES



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ABSTRACT

This paper is an attempt to assess the influence of breed and pre-slaughter management on the subsequent pH history of the carcase, and to establish any connection with lean meat quality. We are studying a year's intake of pigs from a single source, and of known breed and management. We now present the results of the first six months.

pH measurements were taken at 45 minutes, 120 minutes and 24 hours after slaughter, and are presented graphically. Different housing conditions have had no effect on pH, but pigs from the sweathouse have had paler lean meat colour. Severe pre-slaughter stress, either from difficulty in loading or high ambient temperature, has increased the ultimate pH. Our Landrace-sired pigs seemed to be more susceptible in general to pre-slaughter stress than our Large White-sired progeny. Stress or excitement at the time of slaughter is associated with an increased proportion of low pH_{120} figures.

Pigs showing marked rigidity 30 minutes after death had low pH_{45} and higher pH_{ult}, and more variable lean meat colour than the general population. Lean meat colour was associated significantly with pH_{120} and pH_{ult}. Soluble protein was significantly associated with all pH values. Water-holding capacity was most closely correlated with pH_{45}. Exudative meat could not be selected on the basis of pH_{45}, but usually had pH_{120} below 5.8. Large White progeny appeared to need a lower pH_{120} than Landrace progeny to produce exudative muscle.

Les effets de quelques variables avant l'abattage des porcs sur les changements post-mortem du pH et l'utilisation du pH dans la détermination des facteurs qualitatifs de la viande maigre.

R. Vetterlein et A.J.Kidney

EXTRAIT

Ce mémoire a pour objectif d'essayer de déterminer l'influence de la race et du traitement précédant l'abattage sur l'évolution du pH de la carcasse et d'établir tout rapport avec la qualité de la viande maigre. Nous avons pris comme base d'étude les porcs abattus en une année venant d'une même source et de race et traitement connus. Nous présentons maintenant les résultats des six premiers mois.

Les mesures du pH ont été effectuées respectivement 45 minutes, 120 minutes et 24 heures après l'abattage et elles sont représentées graphiquement. Les conditions différentes de logement n'ont eu aucun effet sur le pH mais la couleur de la viande maigre chez les porcs ayant séjourné dans le "box irlandais" (haute température, haute humidité) était plus claire. Une forte tension avant l'abattage à la suite de difficultés de maniement ou d'une température ambiante élevée a augmenté le pH ultime. D'une manière générale, nos porcs de pères de race Landrace sembleraient plus prédisposés à la tension avant l'abattage que ceux de pères de race Large White. La tension ou la surexcitation au moment de l'abattage correspond à une plus grande proportion de valeurs pH_{120} faibles.

De tous les porcs étudiés, ceux présentant une rigidité prononcée 30 minutes après l'abattage avaient une valeur pH_{45} faible et une valeur pH_{ult} plus élevée que les autres, et la couleur de la viande maigre en était plus variable. On a établi un rapport significatif entre la couleur de la viande maigre et le pH_{120} et le pH_{ult}. On a constaté qu'il existe entre la protéine soluble et toutes les valeurs pH une liaison significative. On a trouvé que le rapport entre le pouvoir de rétention d'eau et le pH était le plus étroit 45 minutes après l'abattage. On n'a pas pu déterminer la viande exsudative sur la base du pH_{45}, mais elle avait généralement un pH_{120} inférieur à 5,8. Il nous a apparu que le porc de père de race Large White devait avoir une valeur pH_{120} plus faible que le porc de père de race Landrace pour produire un muscle exsudatif.

Über die Auswirkungen einiger der Schlachtung von Schweinen vorausgehenden variablen auf die post-mortem pH-Veränderungen und die Verwendung des pH-Wertes fur die Voraussage der Qualitätsfaktoren im mageren Fleisch.

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KURZFASSUNG

Diese Arbeit ist ein Versuch, den Einfluss von Rasse und Behandlung der Schweine vor der Schlachtung in Bezug auf die folgende pH Wertveränderung des Schlachtkörpers auszuwerten und Zusammenhänge mit der Qualität des mageren Fleisches festzustellen. Wir beobachten eine einjährige Aufnahme von Schweinen, von einer einzigen Quelle bezogen und von bekannter Rasse und Behandlung.

Nachstehend geben wir die Resultate des ersten Halbjahres.

Die pH Werte wurden nach 45 Minuten, 120 Minuten und 24 Stunden nach der Schlachtung gemessen und graphisch dargestellt. Unterschiedliche Aufstallung hatte keinen Einfluss auf die pH Werte, dar magere Fleisch der Schweine aus dem Saunestall war jedoch blasser. Starke Beanspruchung vor der Schlachtung, wie Transportschwierigkeiten oder hohe Umgebungs-temperatur, erhöhte den schliesslichen pH Wert.

Unsere Schweine, die von Vatertieren der Landrasse abstammten, schienen für Beanspruchungen vor der Schlachtung anfälliger zu sein als die Nachkommenschaft von Large White Vatertieren. Beanspruchung oder Aufregung zur Zeit der Schlachtung ist mit einem erhöhten Anteil von niedrigen pH_{120} Werten verbunden.

Schweine mit deutlicher Steifheit 30 Minuten nach dem Tod zeigten niedrigen pH_{45} und höheren pH_{ult}, sowie unterschiedlichere Färbung des mageren Fleisches als im allgemeinen. Die Farbe des mageren Fleisches hing signifikant mit dem pH_{120} und pH_{ult} zusammen. Lösliches Protein stand signifikant im Zusammenhang mit allen pH Werten. Das Wasserbindevermögen war am engsten korreliert mit pH_{45}. Eine Identifizierung von exudativem Fleisch konnte nicht auf der Basis von pH_{45} erfolgen. pH_{120} lag jedoch im allgemeinen unter 5,8. Nachkommenschaft der Large White Vatertiere schien einen niedrigeren pH_{120} Wert zu benötigen als die der Abstammung Landrasse, um exudativen Muskel zu erzeugen.