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A Survey of pH_1 and Ultimate pH Values of British Progeny-tested Pigs, carried out by the British Meat Research Institute and P.I.D.A.

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by

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The present survey of the pH_1 and ultimate pH values of British progeny-tested pigs from five stations was undertaken to run concurrently with the broad survey of commercial pigs, carried out by the B.F.M.I.R.A and reported in a separate communication by Dr. Taylor. We also tested, when practicable, a like number of commercial pigs in each of the factories where the progeny pigs were slaughtered, so that direct comparison between the two types could be made under identical conditions.

The methods used were the same as those described by Dr. Taylor, but the pH_1 values, measured 45 mins. after death, were usually taken in the longissimus dorsi muscles (LD) at the level of the last rib, instead of in the gammon muscles*, exposed by splitting, although a considerable number of values for gammons are also available.

The results show that there is a significantly greater tendency towards wateriness in the progeny-tested pigs than in the commercial, as judged by the numbers of pH_1 values lying below pH 6.0. The mean pH_1 values of the progeny-test pigs are, however, close to those reported by Dr. Taylor for his commercial pigs, although somewhat lower than those for the commercial pigs examined in this study.

A distinctive feature of our results is that CO_2-stunning produced lower pH_1 values than the more usual electric stunning, and hence a greater tendency towards watery pork, both in progeny-test and commercial pigs. These differences were highly significant.

Another factor which affected the pH_1 values significantly was the time between leaving the progeny-testing stations and slaughter, which, as it was increased, tended to give rise to lower average values and a significantly greater number below pH 6.0. This effect was independent of the ambient temperature.

* The main gammon muscles exposed by splitting the pig are the semi-membranosus and the adductor. The value used for each pig is the mean of 3 values in each of these muscles.

RESULTS

Before discussing the results in detail, we must describe the method we have employed to test the significance of the differing distributions of pH_1 values, due to differing treatments or methods of slaughter. We are particularly interested, not in the general distribution, but in the % of values below pH 6.0 (low pH_1 values), because it is these which reveal the tendency to wateriness in any particular batch of pigs. Since the pigs were slaughtered, in weekly batches of about 20, on the same day of the week at each factory, we can use these batches as the unit, and calculate the % of low pH_1 values in each batch, and then the mean % value for a number of batches, treated in the same way. This mean value can then be compared with the mean of a similar number of batches, treated in a different way, and the significance of the difference between the two means tested by the t-test or the F-test. As far as possible, the total number of pigs in each test group should be similar. This batch-wise method of testing has been used, for instance, in the calculation of the standard errors of the means and the significance of the differing conditions given in tables 2 and 3; in the former case for the effect of differing ranges of ambient temperature, and in the latter for the effect of 'waiting' time at the various factories.

a) Overall results for progeny-tested and commercial pigs, and the effect of breed.

Fig. 1a shows the frequency polygons for the pH_1 values of all the progeny-test and commercial pigs investigated, except those stunned by CO_2. The results cover the period from June, 1964 to May 1965.

It is seen that both polygons are somewhat skewed, but the one for the progeny pigs is broader and shifted more towards lower pH_1 values than that for the commercial pigs. The mean pH_1 values for progeny-test and commercial pigs are respectively pH 6.50 and 6.62, and the percentages below pH 6.0 are 6.6 and 1.8% (see table 1). When tested as outlined above, these percentages were found to differ significantly at the 0.1% level of probability.

There are considerable differences between the three progeny-test breeds as shown in fig. 1b, and table 1, where the average pH_1 value for Welsh and Landrace pigs, combined, is 6.42, compared with 6.52 for Large White, and the percentages below pH 6.0 are respectively 10.5 and 3.9%. These differences are significant and also show up on much smaller samples. It would be more difficult, however, to distinguish Large White progeny from commercial pigs, as we see by comparing fig. 1a with fig. 1b.

b) The effect of the method of stunning.

CO_2-stunning was used at one of the factories (factory 2) where progeny-test pigs were slaughtered, whereas the other four factories used electric stunning. The overall effect on progeny-test pigs is shown in fig. 2a, where we see that the use of CO_2 has shifted the frequency polygon quite markedly to lower pH_1 values, so that the mean value for CO_2 is pH 6.33, compared with 6.50 for electric stunning, and the percentages below pH 6.0 are respectively 18.1 and 6.6%. These latter differences are highly significant (P = 0.1%). Note that this effect is quite independent of breed, since the breeds were represented to more or less the same extent in the CO_2 and electrically-stunned groups.

The overall effect on commercial pigs is similar, as seen from table 1, where the average pH_1 value is lowered by CO_2 stunning from 6.62 to 6.47, and the percentage below pH 6.0 is raised from 1.8 to 5.5%. Thus, CO_2 stunning can increase the tendency to watery pork in commercial pigs beyond that for the Large White progeny stunned electrically, where the % below pH 6.0 = 3.9%.

To show that this effect was not due to some condition at the factory other than CO_2 stunning, we tested two groups of 61 pigs at factory 2, one stunned with CO_2 and the other electrically. The result is shown in fig. 2b, from which it is obvious that CO_2 is the cause and gives a mean value of 6.27 for pH_1, and a % below pH 6.0 of 25.6 %, compared with values of pH 6.50 and 14.4%, respectively, for the electrically-stunned group. It is also seen that the frequency polygon for the CO_2-stunned group has become bimodal, the first mode lying at pH 6.30 and the second at pH 5.90. This is also a feature of the frequency polygons for Danish Landrace pigs, where the % of values lying below pH 6.0 can often exceed 30%.

Incidentally, the differences between breeds are brought out rather more clearly by CO_2 stunning than electrical stunning. Thus, 12.2% of the pH_1 values for 280 Large White pigs, stunned with CO_2, were below 6.0, while for a group of 280 Welsh and Landrace pigs, the % below 6.0 was 24.0%.

c) LD muscles and gammons, compared.

We have tested the difference in pH_1 values between LD muscles and gammons on 202 progeny-test pigs. As table 1 shows, the mean pH_1 value in LD muscles is lower than in gammons, whereas in this particular sample the frequency polygon for gammons was more skewed than that for LD muscles, so that the former showed a rather higher % of values below pH 6.0. The latter difference was not significant, whereas the difference between the values for pairs on the same carcase was significant at the 1% level of probability. By this test, the LD muscles had a pH_1 value 0.056 units lower than that for the gammon of the same animal ($t = 2.6$, for $n = 202$). However, the standard error of the difference was high ($\pm$ 0.022), giving a standard deviation for this number of values of $\pm$ 0.31. This means that pigs showing the watery condition in their LD muscles need not necessarily do so in their gammons, and vice-versa, although for the purpose of an overall survey, it makes little or no difference to the shape or position of the frequency polygons which muscle group is chosen.

d) <u>The effect of sex</u>.

The effect of sex on the pH_1 values has been tested on 535 pairs of progeny gilts and hogs, and also on 52 entire males. The mean pH_1 value for gilts was 6.43 and that for hogs 6.45, and the % of values lying below pH 6.0 were 10.1 and 9.9% respectively. The small sample of entire males gave almost identical average values. Thus, sex has no significant effect on pH.

It should be noted that the reason for the rather high % of values lying below 6.0 in this series is that about ⅓ of the pigs in each group were CO_2-stunned.

e) <u>The effect of position on the line</u>.

As we will show in section g), the incidence of low pH values increases as the average time between leaving the progeny-testing stations and slaughter increases; we would therefore expect that the last pigs to be slaughtered in a batch would have a higher incidence than the first. To show whether or not this was so, we compared the incidence of low pH_1 values in the first half of the slaughter lines with that in the second half. We chose days on which between 15 and 40 pigs were slaughtered in a batch (average batch size = 23 pigs). All breeds were included, but they were quite randomly dispersed throughout the batches, so that this factor could not have affected the results.

At factory 1 (electrical stunning), the mean % of pH_1 values below pH 6.0 per batch was 8.6% in the first half of the lines and 12.2% in the second half (total number of pigs = 568; number of batches = 26). The difference between these percentages was tested batchwise by the t-test, but was not significant, because of the high variance. A similar result was obtained at factory 2, where CO_2-stunning was used and the % of low pH_1 values was therefore higher. In the first half of these lines, the mean % of low pH_1 values per batch was 15%, and in the second half 21% (total number of pigs = 466; number of batches = 19). Again because of the high variance, the difference between these mean % values was not significant.

As a further test, we applied the same criterion, batch by batch, to 600 Large White pigs; 300 in each half of the lines. The mean % of low values in the first half was 5.3% compared with 7.3% in the second half, but again the difference was not significant. Thus although statistically insignificant, there does appear to be a definite trend towards lower pH_1 values in the second half of any slaughter line compared with the first half, no matter what method of stunning or breed of pig is investigated, because of the increase in waiting time.

f) <u>The effect of season and external temperatures.</u>

The effect of season was examined at factory 1, where four quarterly periods were considered, during each of which approximately 220 pigs of all breeds were slaughtered. The % of pH_1 values below pH 6.0 were: 6.2% from June to August, 1964, inclusive; 8.6% from September to October, 1964; 11.7% from December, 1964 to February, 1965; and 8.3% from March to May, 1965. The mean pH_1 values were respectively: 6.50, 6.45, 6.46, and 6.47. Thus the effect of season is the reverse of what would be expected, the early summer showing a lower % of low pH_1 values than the autumn, winter and spring, although none of these differences are significant statistically, when tested batchwise, as we have described.

To a certain degree, the above values should also reflect the effect, if any, of the ambient temperatures in the holding and sticking pens, which closely follow the seasonal changes in external shade temperatures. More detailed analysis of the effect of ambient temperature at factory 1 is given in table 2, where we observe the curious phenomenon that the lowest % of low pH_1 values occurs in the highest of the four arbitrarily chosen temperature ranges. The difference between the values for this range and those for the lowest range but one is, however, the only one which is statistically significant (at the 3.5% level of P).

Thus the effect of temperature, like that of season, is the opposite of what has commonly been supposed to be the case. Danish workers, for instance, have claimed that the severity of fighting in the holding pens increases with ambient temperature, and with it the % of low pH_1 values. The above results do not support this claim, under English conditions.

g) <u>Variability of the occurrence of low pH_1 values from factory to factory, and the effect of holding time in the pens upon it.</u>

The variability between the four factories, using electrical stunning, in average pH_1 values and in the % of these values below pH 6.0, is shown in table 3. None of this variability is due to seasonal or temperature effects, because the batches were compared over the same period, from Oct. 1964 to May, 1965. The effect of breed has also been eliminated by working out the % of low values separately for Large White and for Landrace plus Welsh at a given factory, and then averaging them. This was necessary particularly in the case of factories 3 and 4 where the % of Landrace plus Welsh was lower than the average of about 50% at the other three factories. It is quite clear, however, that there is a high degree of correlation between the time taken on the journey from progeny-testing station to factory plus the time in the holding pens, on the one hand, and the % of low pH_1 values, on the other, as seen by the highly significant differences between the mean values for batches, given in the table. The corollary is that the average pH_1 values fall as the total time between leaving the stations and slaughter increases. In other words the pigs become excited and tensed up during their journey by truck and in the holding pens, and this leads to lower pH_1 values the longer it lasts. The possible physiological reasons for these effects are discussed by one of us (J.R.B.) in another contribution to this meeting.

It will be noted from table 3 that, at the factory where the 'waiting' time was shortest (factory 3), the mean pH_1 value and the % of low values were very close to the overall mean values for the commercial pigs tested in this study (c.f. table 1 and fig. 1a). This is brought out more clearly by the frequency polygon, shown in fig. 3, for the pH_1 values of the Large White pigs at this factory, which is even sharper than that for the commercial pigs in fig. 1a. In contrast, the frequency polygon for factory 1, where the 'waiting' time was one of the two longest, is much broader and has a more extensive area in the lower ranges of pH.

These results lead one to wonder whether there would be any significant difference in pH_1 values, and hence in tendency to wateriness, between progeny pigs and the very mixed breeds of the commercial group, if all the pigs had been brought up in the same manner. Progeny-test pigs are notoriously coddled and are kept alone or in small groups in temperature-controlled sheds, whereas many commercial pigs are used to living together in larger groups, often on free range. Thus the progeny-test pigs are far more likely than commercial pigs to become unduly excited, when suddenly transported from their private homes, as it were, in the company of querulous neighbours.

h) The effect of deep muscle temperature after slaughter, and its relation to ambient temperature in the factory.

It has been claimed by one school of American workers (see contribution by JRB for references) that cooling down pigs in water before they are slaughtered leads to lower deep muscle temperatures after slaughter, and, therefore, to higher pH_1 values and less watery meat. It might be thought that low ambient temperatures would have the same effect, particularly when the time in the holding pens is extended. We therefore first tested these effects at factory 1, where the holding time averaged $1\frac{1}{4}$ hours. We found a deep muscle temperature in the LD muscles of 842 pigs, at 45 mins. after slaughter, of 38.8°C, from June, 1964 to May, 1965 (see table 3). During one period of four weeks in Jan/Feb., 1965, however, the mean ambient temperature in the factory dropped to 4.5°C. The mean deep muscle temperature of these pigs, instead of being lower as expected, was on the contrary 40.4°C, that is 1.6°C higher than average. In spite of this higher muscle temperature, however, the % of pH_1 values below pH 6.0 dropped from the overall mean value of 9.5% to 6.85% (i.e. 5 pigs out of 73). Thus, the reactions of muscle temperature to ambient temperature and of pH_1 to muscle temperature were exactly the opposite to expectation.

Considering the other factories using electrical stunning, we see from table 3 that, although the mean muscle temperature varies slightly from factory to factory, it again bears no relation to the % of low pH_1 values. In fact, factory 3 which is the best from the point of view of pH_1 shows one of the highest mean muscle temperatures.

From these results, it is evident that we can abandon the idea that ambient temperature has any clear-cut effect on deep muscle temperature after slaughter, and thus indirectly on the occurrence of wateriness, at least as far as British pigs are concerned.

i) Factors affecting the ultimate pH values.

The ultimate pH values for the pigs killed at all 5 factories are given in table 3. It is noticeable that there is a tendency for the ultimate pH to rise as the time between leaving the stations and slaughter increases. This effect is probably due to prolonged excitement and muscular tension, leading to utilisation of more of the glycogen reserves in the muscles. Again, the pigs at factory 3, which have the highest mean pH_1 values, indicating the least excitement and muscular tension, show the lowest mean ultimate pH, that is the highest reserves of glycogen in the muscles at slaughter.

It is interesting to note that the overall mean ultimate pH of 5.68, for all the progeny pigs is considerably higher than that of about 5.50 usually found in large samples of Danish Landrace pigs. It is also higher than the mean value for the 10 Large White pigs used by Bendall in a study of the effect of curarisation to be presented at this meeting. The latter pigs were, however, kept under very carefully controlled conditions, with the least possible excitement before slaughter.

Factors which do not seem to affect the ultimate pH significantly are sex, breed or method of stunning. Thus gilts and hogs cannot be distinguished from one another, nor can Large White, Welsh or Landrace of either sex, nor can CO_2-stunned pigs and electrically stunned pigs, as we see from table 3.

Another factor which has been shown by some workers to lower the glycogen reserves, and thus to raise the ultimate pH, is exposure to low ambient temperatures for extended periods, no doubt due to shivering. The longest exposure to extremes of ambient temperature in our experiments was $1\frac{1}{2}$ hours, as at factory 1. This, however, was evidently not sufficient to have any effect whatsoever on the ultimate pH values, as we see from the values for the four arbitrarily chosen temperature ranges, given in table 2. Even at the extremes of ambient temperature of 22.2°C and 4.3°C, the mean ultimate pH did not vary from 5.75 by more than 0.01 unit.

Thus the only factor we have found to have any effect on ultimate pH is the time between leaving the station and slaughter, and this effect is quite independent of the ambient temperature. This 'waiting time' has an effect on ultimate pH of about the same order as it does on the mean pH_1 values.

A factor we have not investigated is feeding, but this was so carefully controlled and consistent from station to station that it is unlikely to come into account with the progeny-test pigs.

SUMMARY

1) A total of 2878 progeny-test pigs from five stations, and of 1532 commercial pigs, were surveyed for the pH_1 values, at 45 mins. after death, and the ultimate pH values, at 24 hours after death, of their LD muscles at the last rib. Values are also available for the heads of the adductor and semimembranosus muscles, where they are exposed in the gammons on splitting the pig.

2) Factors which affect the pH_1 values are the method of stunning, the breed of pig and the waiting time between station and factory, before slaughter.

a) CO_2 stunning lowers the mean pH_1 values and increases the % of these values lying below pH 6.0 about 3 fold, as compared with electrical stunning. The effect is easily detectable. In extreme cases, a distinctly bimodal distribution of the pH_1 values appears in CO_2-stunned pigs.

b) Of the progeny-tested breeds, Large White shows the lowest % of low pH_1 values and Welsh and Landrace the highest, but the differences (about 2 fold) are not as marked as those brought about by changing from electrical to CO_2-stunning of any particular breed. Commercial pigs of mixed breed, for instance, show a lower % of low pH_1 values even than Large White, but this % can be raised beyond that for electrically stunned Large White, if the commercial pigs are stunned with CO_2.

c) Waiting time between leaving the station and slaughter has a marked effect on the shape and position of the frequency polygons for pH_1. As the time is increased, so the frequency polygons become broader, the mean pH_1 shifts to lower pH values and the % of values below pH 6.0 increases. At the shortest waiting times, the frequency polygons and the other two parameters for progeny-tested pigs are almost identical with those for commercial pigs, and may even be an improvement on them, in the sense that the tendency to watery pork is further decreased. This effect of waiting time is independent of ambient temperature, which itself affects the distribution of pH_1 values but only to a minor degree. There is, similarly, a tendency for the % of low pH_1 values to be affected by season, being lower in spring and early summer than in autumn and winter, contrary to expectation.

3) Factors which do not significantly affect the distribution of the pH_1 values, or their mean, are the sex of the pig, and the deep muscle temperature at 45 mins. after slaughter. In fact, the pH_1 values are completely randomly distributed with respect to deep muscle temperature which in its turn appears to be quite unrelated to the ambient temperature in the holding pens or the factory.

4) There are some differences between the pH_1 values of gammon and LD muscles, the former tending to be slightly higher on average, but randomly distributed, so that a pH_1 value of below 6.0 in the LD muscle may be accompanied, on the same carcase, by one of 6.30 or higher in the gammon or vice-versa. For the purposes of an overall survey of the likely occurrence of watery pork, the differences between the two muscles are negligible; but they would clearly disturb any supposed inbred tendency on the part of sires or dams of the progeny, to produce watery pork, since a set of results, obtained on gammons, would, as likely as not, be contradicted by a set on LD muscles.

5) The ultimate pH values of the progeny-tested pigs are raised as the waiting time before slaughter increases, due no doubt to increased utilisation of glycogen reserves during the tension and excitement of waiting. Ambient temperature, on the other hand, has no significant effect on the ultimate pH, even at the longest waiting time of 1½ hours, although the pigs may have been exposed during this time to temperatures below 4.5°C. Hence, the wastage of glycogen by shivering, observed by earlier workers, does not seem to occur here.

The grand mean of all the ultimate pH values was 5.68, which is higher than that of 5.50 usually observed in large samples of Danish Landrace.

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Résumé

1) 2878 porcs à descendance contrôlée, provenant de 5 centres de production différents, ainsi que 1532 porcs commerciaux ont subis des mesures de la valeur du pH_1 à 45 minutes après l'abattage, et du pH ultime effectuées 24 heures après la mort, dans le muscle Longissimus dorsi au niveau de la dernière cote. Des mesures ont aussi été obtenues pour les extrêmités des muscles adducteurs et semi-membranosus exposés dans les jambons après la fente des carcasses.

2) Quelques facteurs qui influent sur les valeurs du pH_1 sont: la manière d'assommer les victimes, la race porcine utilisée et la période d'attente après avoir quitter le centre de production et avant l'abattage.

a) Si l'on assomme par l'intermédiaire de CO_2, on abaisse la moyenne du niveau de pH_1 et on augmente le pourcentage des valeurs de pH situées en-dessous de 6.0, à peu près trois fois en comparaison avec le procédé par choc électrique. Dans les cas extrêmes, une distribution nettement bimodale du pH_1 s'accuse chez les porcs traités au CO_2.

b) Parmi les races ayant subies une descendance contrôlée, le porc Large White manifeste le pourcentage le moins élevé de valeurs de pH_1 faibles et le Welsh et le Landrace donnent les pourcentages les plus élevés. Cependant ces différences (les unes sont à peu près 2 fois les autres) ne sont pas aussi marquées que celles qu'on obtient pour n'importe quelle race en passant de l'emploi du choc électrique à celui du CO_2. Par exemple, les porcs commerciaux de race mixte donne un pourcentage des valeurs de pH_1 encore moins élevé que celui des Large White, mais ce pourcentage peut atteindre un niveau au-dessus de celui de porcs Large White traités par choc électrique si les porcs commerciaux sont traités au CO_2.

c) La période d'attente depuis le déplacement hors du centre de production jusqu'à l'abattage, entraîne des variations marquées de la forme et de la position des polygones de fréquence pour le pH_1. A mesure que la durée augmente, les polygones de fréquence deviennent plus larges, le valeur moyenne du pH_1 s'abaisse et le pourcentage des valeurs au-dessous de 6.0 augmente. Pour les durées les plus courtes, les polygones de fréquence et les 2 autres paramètres pour les porcs à descendance contrôlée, sont presque les mêmes que ceux des porcs commerciaux, ils peuvent même être meilleurs en ce sens que la tendance à l'exsudation est encore plus diminuée.

Cette influence de la période d'attente est indépendante de la température ambiente qui elle-même influe sur la distribution des valeurs du pH_1, mais à un moindre degré. Il y a également une tendance à varier selon la saison pour ce qui concerne les pourcentages des valeurs inférieures du pH_1, les valeurs étant plus abaissées au printemps et au début de l'été qu'en automne et en hiver. On pourrait s'attendre au contraire.

3) Parmi les facteurs qui n'influent significativement ni sur la distribution du valeurs de pH_1, ni sur la valeur moyenne, on peut citer le sexe du porc et la température du muscle intérieur à 45 minutes post-mortem. En effet

/les valeurs

les valeurs du pH_1 sont distrubées d'une façon complètement indépendantes pour le température du muscle intérieur qui, à son tour, semble être indépendante de la température ambiente dans les parcs ou à l'usine.

4) Quelques différences se manifestent entre les valeurs du pH_1 des muscles du jambon et celles du muscle Longissimus dorsi. Les premières ont tendance à être, en moyenne, plus élevées mais se place d'une manière fortuite dans leur distribution. Ainsi une valeur du pH_1 de moins de 6.0 dans le muscle Longissimus dorsi peut s'accompagner dans une même carcasse d'une valeur de 6.30 ou même plus dans le jambon, ou vice-versa.

Pour effectuer une étude générale des temoins possibles de l'état exsudatif les différences entre les 2 muscles restent sans importance, mais elles porteraient atteinte évidemment à toute estimation d'une tendance innée, chez les parents, mâles et femelles de la descendance, à produire l'état exsudatif, puisque un groupe de résultats obtenus sur des jambons serait, sans doute, démenti par un autre groupe de résultats provenant du muscle Longissimus dorsi.

5) Les valeurs du pH ultime s'élévant par rapport à l'augmentation de la durée d'attente avant l'abattage. Ceci résulte, sans aucon doute, de l'utilisation intensifiée des réserves de glycogène amenée par l'excitation et la tension provoquées par l'attente. Par contre, la température ambiente n'influe pas sur le pH ultime, même après la période d'attente la plus longe, c-à-d. de $1\frac{1}{2}$ h. quand même les porcs auraient subi, pendant cette période, des températures en-dessous de 4.5°C. De ce fait, il semble que la dépense de glycogène qui est entraînée par le frissonnement (observée déjà, par d'autres chercheurs) ne s'est pas produite ici.

La moyenne globale de toutes les valeurs du pH_2 ultime était de 5.68, ce qui est plus élevé que la valeur de 5.50 généralement indiquée pour les gros échantillons de Landrace danois.

Zusammenfassung

1) Eine Gesamtzahl 2878 Zuchtschweine aus fünf Anstalten und 1532 Mastschweine wurde in Bezug auf den pH-Werten 45 Minuten nach dem Tode und den endgültigen pH-Werten 24 Stunden nach dem Tode seiner LD-Muskeln bei der letzten Rippe geprüft. Auch für die Kopfenden der M. adductor bzw. semimembranosus, wo sie nach der Zerspaltung des Schweines in den Schinken blossgelegt sind, stehen Werte zur Verfügung.

2) Faktoren, die die pH-Werte beeinflussen, sind das Betäubungsverfahren, die Rasse des Schweins und die Dauer des Wartens von der Anstalt zur Fabrik, vor dem Schlachten.

a) Die CO_2-Betäubung setzt die Durchschnitts-pH-Werte herab und vermehrt das % der unter pH 6.0 liegenden Werte ungefähr dreifach, im Vergleich mit der elektrischen Betäubung. Die Wirkung ist leicht erkennbar. In äussersten Fällen kommt in CO_2-bestäubten Schweinen ein deutlich bimodalische Verteilung der pH_1-Werte vor.

b) Unter den Zuchtschweinerassen zeigt die Large-White das geringste % niedriger pH_1-Werte und die Welsh und Landrasse das grösste, aber die Unterschiede (ungefähr zweifach) sind nicht so auffallend als die, die durch einen Übergang von der elektrischen auf der CO_2-Betäubung bei einer gegebener Rasse verursacht sind. Mastschweine einer gemischten Rasse, zum Beispiel, weisen ein geringeres % niedriger pH-Werte auf als die Large-White selbst, aber dieses % kann über jenes bei elektrisch betäubten Large-White-Schweinen beobachtete % steigen, wenn die Mastschweine durch CO_2 betäubt werden.

c) Die Dauer von der Abfahrt von der Fabrik bis zum Schlachten hat auf der Form und Lage der Häufigkeitspolygone des pH_1-Wertes eine auffallende Wirkung. Wurde die Dauer vergrössert, so werden die Häufigkeitspolygone breiter, und es ändert sich der Durchschnitts-pH_1-Wert zu niederen pH-Werten und vermehrt sich das % der unter pH 6.0 liegenden Werte. Bei den kürzesten Wartezeiten sind die Häufigkeitspolygone und die andere zwei Parameter bei Zuchtschweinen den bei Mastschweinen nachzuweisenen fast gleich, und können auch eine Verbesserung auf diesen sein, und zwar in dem Sinne, dass die Neigung zum wässrigen Schweinefleisch weiter vermindert wird. Diese Wirkung der Wartezeit hängt von der Temperatur der Umgebung nicht ab, die selbst die Verteilung der pH_1-Werte beeinflusst, aber nur in geringem Masse. Das % der niedrigen pH_1-Werte zeigt gleichfalls eine Neigung, durch die Jahreszeit beeinflusst zu werden, und ist, wider Erwarten, niederer im Frühling und frühen Sommer als im Herbst und Winter.

3) Faktoren, die weder die Verteilung noch den Durchschnitt der pH_1-Werte nicht bedeutsam beeinflussen, sind das Geschlecht das Schweines, und die Temperatur des tiefen Muskels 45 Minuten nach dem Schlachten. In Bezug auf die Temperatur des tiefen Muskels, die gleichfalls von der Temperatur der Umgebung in den Fassungsställen oder der Fabrik völlig unabhängig zu sein scheint,

sind die pH_1-Werte in der Tat völlig zufällig verteilt.

4) Es gibt einige Unterschiede zwischen den pH_1-Werten des Schinkens und diesen des LD Muskels; jene Werte sind geneigt, im Durchschnitt ein wenig höher aber noch zufällig verteilt zu sein, so dass ein pH_1-Wert von unter 6.0 im LD Muskel im gleichen Tierkörper von einem Wert von 6.30 oder höher im Schinken begleitet sein kann, oder umgekehrt. Zwecks einer Gesamtübersicht des wahrscheinlichen Vorkommens des Wässrigen Schweinefleisches sind die Unterschiede zwischen den beiden Muskeln unbedeutend; sie wurden aber bei männlichen oder weiblichen Stammtieren der Nachkommenschaft alle ererbte Neigung, wässriges Schweinefleisch zu geben, offenbar stören; denn eine Reihe von Schinken erhaltener Ergebnisse würde wahrscheinlich die Reihe von LD Muskeln erhaltener Ergebnisse widersprechen.

5) Die endgültigen pH-Werte der Zuchtschweine sind mit einer Zunahme der Wartezeit vor dem Schlachten erhöht; dies ist sicher auf erhöhte Verbrauch der Glykogenreserven während der Spannung und Aufregung des Wartens zurückzuführen. Die Temperatur der Umgebung, andererseits, hat keine bedeutsame Wirkung auf die endgültige pH-Wert, auch bei der längsten Wartezeit von $1\frac{1}{2}$ Stunden, obwohl die Schweine während dieser Zeit Temperaturen unter 4.5°C ausgesetzt sein dürften. Der Verlust des Glykogens durch das Schauern, den frühere Forscher beobachtet haben, scheint hier daher nicht vorzukommen. Das Hauptmittel aller endgültigen pH-Werten war 5.68, was höher ist als das 5.50, das in grossen Mustern der dänischen Landrasse-Schweine normalerweise zu beobachten ist.

Table 1.

Summary of mean pH_1 values for all pigs.

Type of pig	Method of stunning	Numbers	Mean pH_1 value	Diff. of mode from mean	% of values below pH 6.0
Progeny (all pigs)	Electric	2312	6.50	+0.20	6.6
	CO_2	566	6.33	+0.33	18.1
Large White	Electric	1360	6.54	+0.16	3.9
Welsh + Landrace	Electric	952	6.42	+0.18	10.5
Special trial at factory 2 on progeny pigs	Electric	61	6.50	+0.30	14.4
	CO_2	61	6.27[x]	+0.03 -0.37	25.6[x]
Commercial pigs.	Electric	1204	6.62	+0.08	1.8
	CO_2	328	6.47	+0.04	5.5
LD muscles & gammons at factory 1. (Electric)	LD	190	6.43	-	6.7
	Gammon	190	6.52	-	7.9

x indicates a bimodal distribution for which the differences of each mode from the mean are given.

Table 2

Effect of ambient temperature on distribution of pH_1 values and ultimate pH values, at factory 1.

	Temp. range °C	Mean temp. °C	Number of pigs	Number of Batches	% of pH_1 values below 6.0	Mean Ultimate pH
(1)	18-26	22.2	193	9	6.2 ±1.4	5.75
(2)	13-17.9	14.4	127	6	11.0 ±3.2	5.74
(3)	8-12.9	10.5	275	14	11.2 ±1.6	5.76
(4)	Below 8	4.3	171	9	8.2 ±2.5	5.76

Table 3

Summary of pH values and deep muscle temperatures, and of the effect of waiting time on them, for progeny-test pigs, over the same period (9/10/64-6/5/65)

Station	Total waiting* time (hrs)	Numbers	Mean pH_1	% below 6.0	Ult. pH	Deep muscle temp. °C.
1 (Elec)	1.50	574	6.46	9.8 ±0.9	5.75	38.8
3 (Elec)	0.50	525	6.61	3.2 ±0.7	5.57	39.5
4 (Elec)	1.25	278	6.43	9.0 ±1.2	5.68	39.0
5 (Elec)	0.75	630	6.53	5.2 ±0.9	5.68	39.9
2 (CO_2)	1.00	566	6.33	18.1 ±2.0	5.66	39.1
Total		2878		Grand Average	5.68	

((1)-(3) Significant at 1.0% level of probability
((1)-(5) " " 1.0% " " "
((1)-(2) " " 0.1% " " "
((3)-(4) " " 1.0% " " "

*total waiting time equals time on route plus time in holding pen.

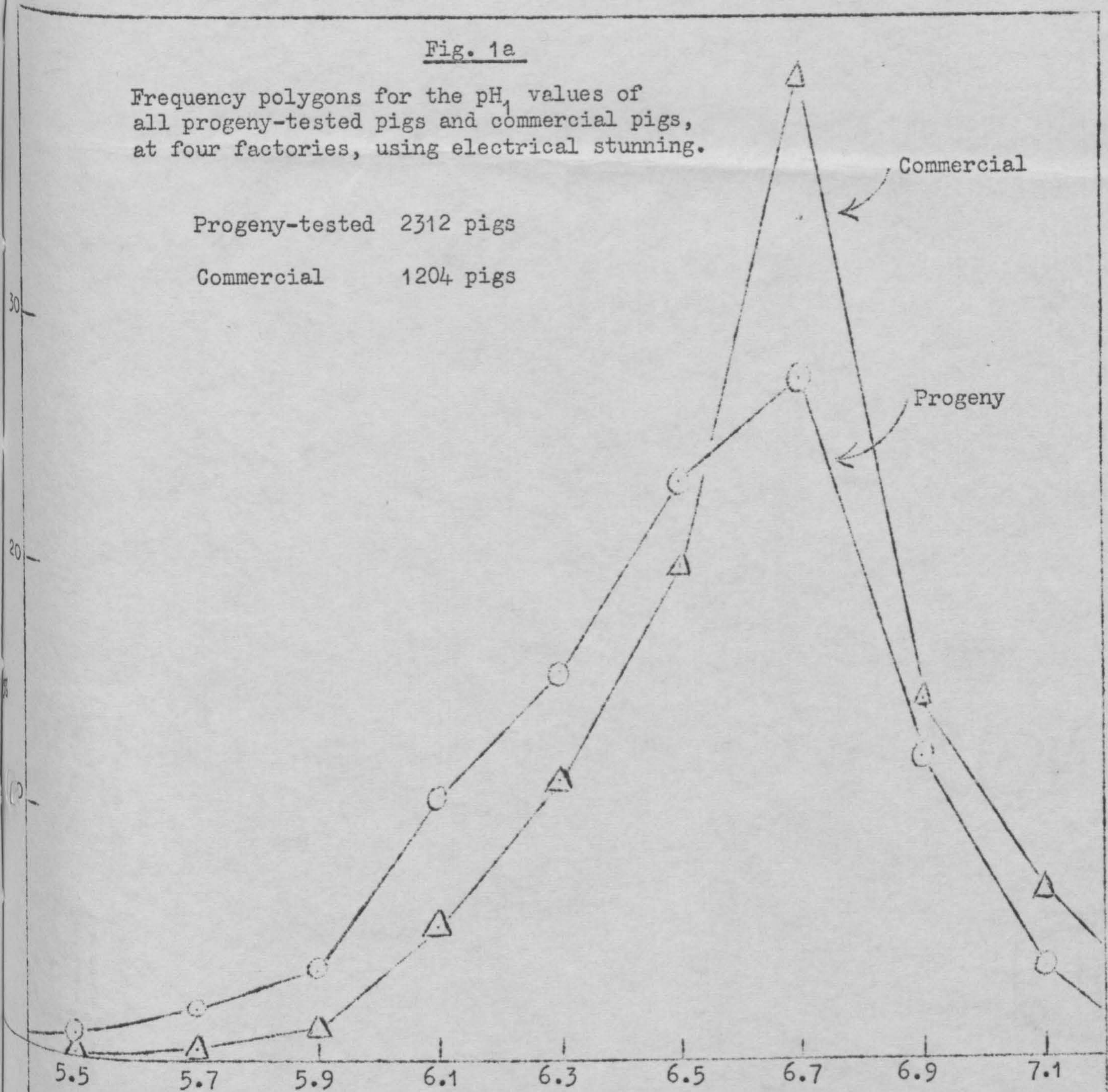

Fig. 1a

Frequency polygons for the pH_1 values of all progeny-tested pigs and commercial pigs, at four factories, using electrical stunning.

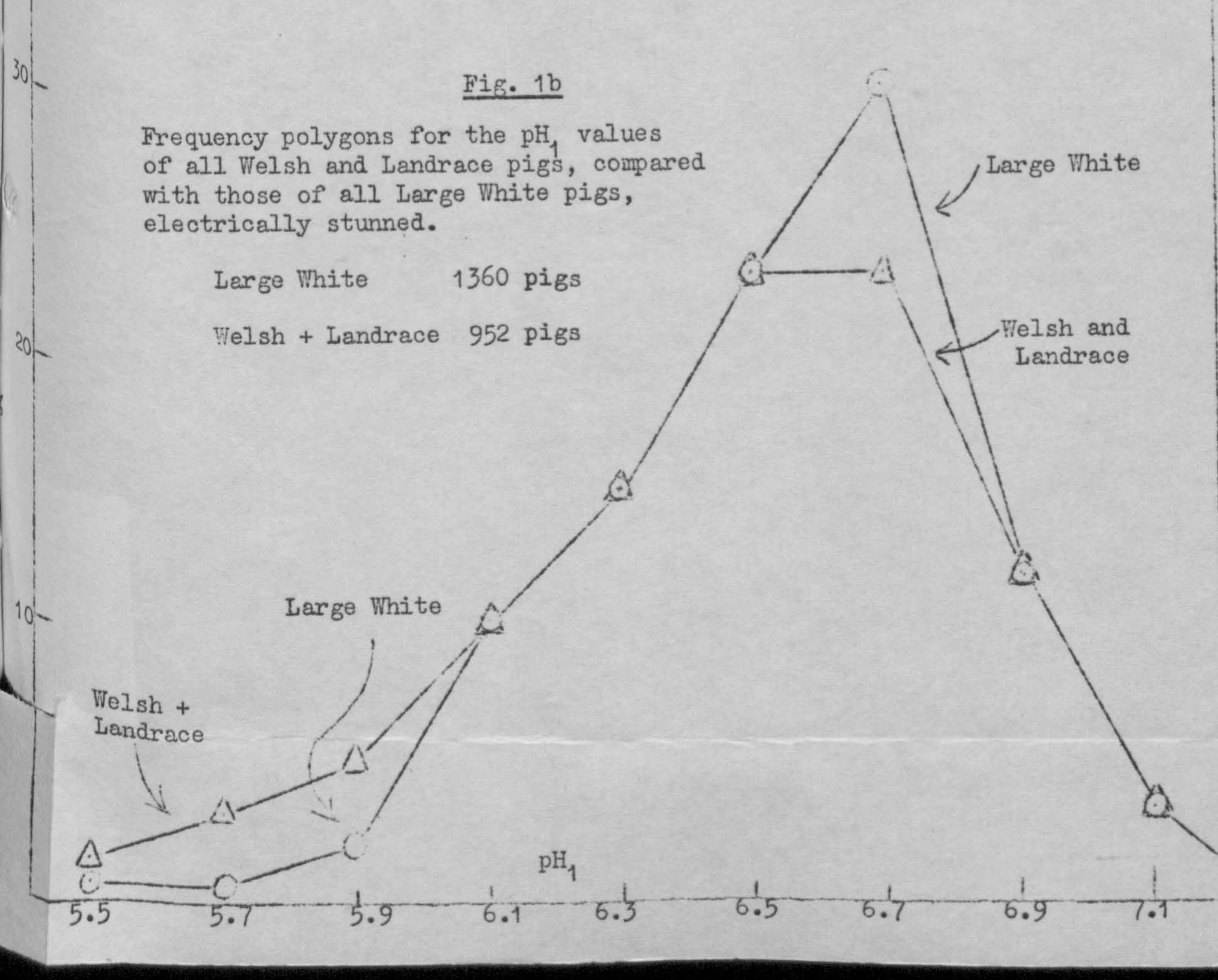

Fig. 1b

Frequency polygons for the pH_1 values of all Welsh and Landrace pigs, compared with those of all Large White pigs, electrically stunned.

Fig. 2 a.

Frequency polygons for pH_1 values of all progeny-tested pigs, stunned electrically, compared with those of pigs stunned with CO_2.

(·) Electric-stunning - 2312 pigs

△ CO_2-stunning - 566 pigs.

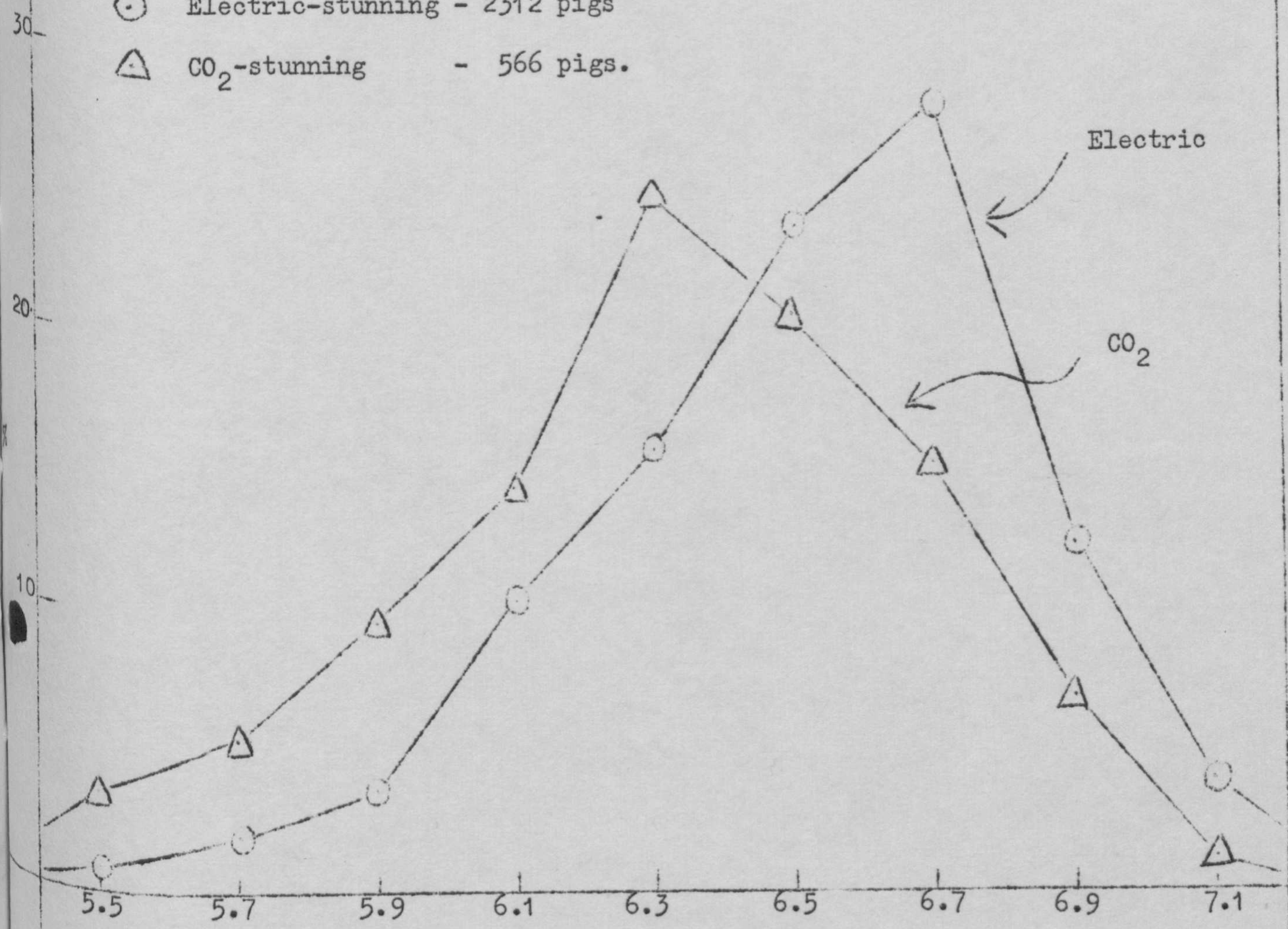

Fig. 2 b.

Frequency polygons for pH_1 values of pigs, stunned with CO_2 or electrically, at factory 2.

61 pigs in each group.

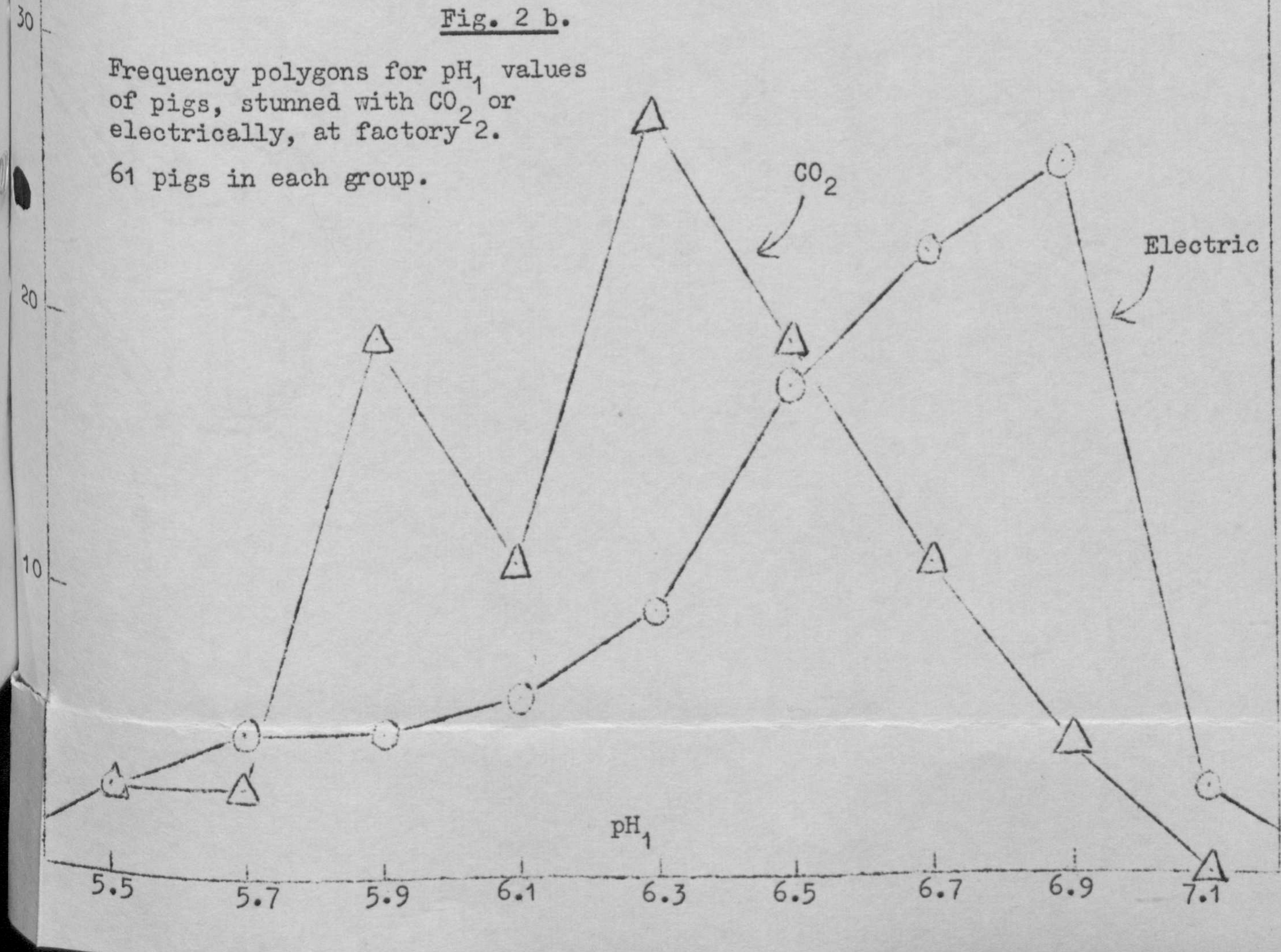

Fig. 3. Frequency polygons for pH_1 values at two of the factories using electric stunning, to show the variability which can occur from factory to factory. (Large White pigs only)

Factory 1: 431 pigs. Mean pH_1 = 6.46. % below 6.0 = 5.9

Factory 3: 408 pigs. Mean pH_1 = 6.61. % below 6.0 = 1.2