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Routine detection of PSE-muscle by dielectric measurement

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Introduction

For the objective detection of porcine PSE-muscles several methods are known. However, none of them is fast enough to enable investigations of all animals on a slaughter line. Measurements of pH value, though being rapid are not exact, not in the least due to maintenance intensive electrodes. Furthermore, for reliable classifications the post mortem pH value as a function of time should be measured, a way, which is too complicated for routine examinations. The use of a single pH value is questionable for classifications /1/. Therefore, additional measurements of other parameters are needed, e.g.,the determination of the "unbound" water content using the method of Grau and Hamm /2/ which, however, is too time consuming. Even the determination of adenine nucleotides by means of UV-absorption-measurement /3/ needs several minutes for procedure, thus being too time consuming for routine detections on slaughter lines.
Different authors tried to use the electric conductivity γ for characterizing the structure of tissue (e.g.,/4/,/5/). However, too weak correlations between PSE-characteristics and γ have been found. Moreover, the geometry of the examined muscle influences the results of conductivity measurements. Thus either the preparation of a defined sample of tissue (being too time consuming) or the evaluation of two measurements taken at different frequencies is necessary.
Examinations of the dielectric properties of muscle tissue according to a method described in /6/ have shown, that PSE-muscles are characterized by increased electric conductivity γ as well as by a decreased dielectric constant ε at frequencies close to 15 kHz. Thus, the so-called dielectric loss factor $d \sim \gamma/\varepsilon$ is increased by a factor of about 10. Finally, the phase angle φ = acot d is changed by approximately one power of ten, thus being significantly decreased. The great advantage of measuring the phase angle φ is, that the geometry of the muscle is almost without relevance. Moreover, the determination of the phase angle φ does not cause any difficulties.

Several effects, depending on each other are responsible for the changed dielectric properties. Partly they can be explained by the increased content of "unbound" water and by increased interstitial spaces respectively (a histological examination will be published later). Furthermore, it is supposed, that changed ionic conditions at the cell membranes are detected, due to a premature post mortem metabolism. This is indicated by the finding, that the dielectric characteristics measured on PSE-muscles immediately post mortem correspond well with those measured on normal muscles after a few days' storage at 4°C /7/.

Instrumental

The measuring device for determination of the phase angle φ impresses a measuring current to the examined muscle by means of two nonerosive steel scalpels. They can be inserted into a plastic handle keeping them parallel to each other in a distance of 25 mm. The relatively large electrode distance ensures an average measurement of a considerably high number of fascicles. Thus a representative result of measurement is obtained. Furthermore, the large distance has the (physical) advantage of reduced polarization effects, thus decreasing errors of measurement /6/. The scalpels are inserted about 25 mm (the exact depth being meaningless) into the examined muscle, the planes of knives being substantially parallel to the muscle fibres.
The phase angle φ between measuring current and voltage is evaluated electronically; the result being displayed within a second. Since no mathematical corrections or evaluations are needed, several muscles can be examined within a few seconds.
As an alternative a microcomputer controlled apparatus developed for routine examinations can be used, which can print out the measuring result and - if desired - interprete automatically. Furthermore, important data can be entered via a keyboard. If the device is connected to a central computer, current records containing each desired information could be listed.
A portable battery-supplied measuring device including a digital display is developed at present.

Material and methods

675 muscles of 429 divided carcasses have been examined. Measurements were taken directly on the slaughter lines of different slaughterhouses during routine slaugh-

tering. Thus, age, sex and breed were randomly sampled. A first measurement of the phase angle φ was taken about 30 minutes post mortem for almost all animals. Further measurements were taken for a part of the animals at different points of time up to two days after slaughtering.

Measurements of pH were taken partly by means of indicator strips and partly by means of an electronic pH-meter. If possible, a first measurement of pH was taken not earlier than 45 minutes post mortem. Measurements of pH could not be executed for all electrically examined muscles, since the carcasses were available only for a short time in many cases.

The content of "unbound" water was determined according to the method of Grau and Hamm /2/. Only about 15% of the muscles electrically examined - preferably muscles showing subjective PSE-characteristics and/or low pH - were checked. Measurements were not taken later than 4 hours after slaughtering.

Furthermore, typical PSE-characteristics concerning colour, consistence and eventual drip were classified subjectively.

675 muscles were measured electrically (328 m. gracilis, 122 m. glutaeus medius, 122 m. longissimus dorsi and 103 m. semimembranosus). All measurements were taken on carcasses divided medially as usual on slaughter lines. The electrodes were inserted into the exposed cut surfaces.

Results

As mentioned above, pH value and water content W as comparison parameters could be partially measured of the electrically examined muscles. In many cases, measurements took place at different moments. Thus, a final evaluation of all parameters is possible only for 52 muscles. For these 52 muscles measurements of pH value and W were taken 45 and 75 minutes post mortem. It is meaningless, that the electric measurements were taken at much earlier points of time (about 30 minutes post mortem): more detailed measurements showed, that the measured phase angle φ does not change substantially within a wide range of time. Thus, φ can be measured at any point of time between slaughtering and 2 hours post mortem. Changes of the electrolytical conductivity due to changes of temperature are meaningless with respect to the distinctly differing phase angles of abnormal muscles (as described below).

Moreover, measurements proved to be relevant even if taken after 24 hours cold storage. However, closer investigations are required.

Fig. 1 shows the phase angle φ versus pH. In literature pH $\leq$ 5.8 often can be found as a - necessary but not sufficient - characteristic for PSE-anomaly /1/. As shown by Fig. 1 phase angle φ was higher than 20° in all cases (with one exception D) of

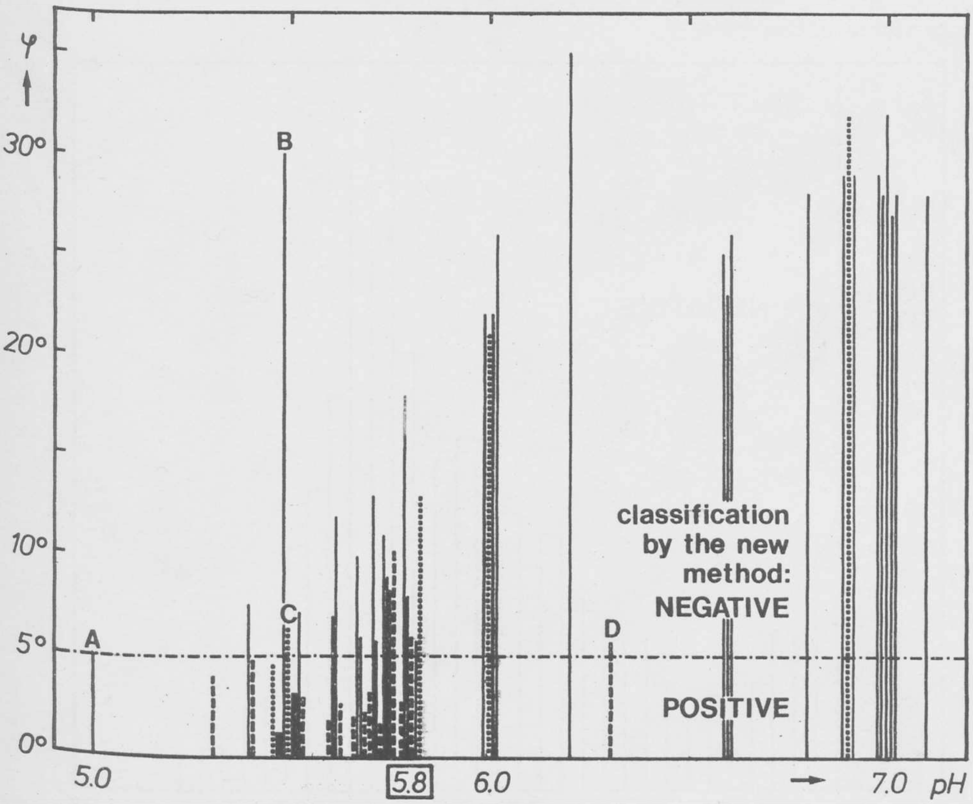

Fig. 1 Phase angle φ versus pH for muscles the investigation of which included also determinations of the water content W

- - - subjective PSE-characteristics

····· high content of "unbound" water ($W \geq 24$)

▬ subjective PSE-characteristics and $W \geq 24$

(52 values)

pH > 5.8, whereas for pH ≤ 5.8 phase angles lower than 20° (also with one exception B) were measured. I.e., a correlation between φ and pH exists, which, however, is meaningless in practice.
Regarding the pH range of 5.0 to 5.8 it becomes obvious, that a number of muscles show very low phase angles. In 15 cases values between 1° and 5° were measured. Our examinations indicate, that in these cases (classified "positive" according to Fig. 1) of extremely low phase angles a muscle anomaly was detected, which obviously is identical with the PSE-anomaly: all "positive" muscles show in addition to the low pH also further PSE-characteristics, i.e., high water content W ≥ 24 and/or external subjective PSE-characteristics. One of the muscles (A) which was classified "positive" neither showed high W nor any subjective PSE-characteristics. Yet its extremely low pH of 5.0 indicates an anomaly also in this case.
On the other hand muscles with pH in the boundary region close to 5.8 and a second PSE-characteristic were classified either "negative" or "positive". Moreover, one muscle (C) with high water content and pH = 5.5 was classified "negative". It needs further investigations to clarify, if such cases of questionable classifications are due to errors in the determination of one or more parameters. However, investigations showed strongly diverging behaviour of the individual muscles of one and the same carcass. In some cases even one and the same muscle showed strongly differing behaviour at different points, especially the m. longissimus dorsi. Generally, our measurements showed, that among the investigated muscles the m. semimembranosus showed the highest values of φ, corresponding with fewest "positive" classifications. Most "positive" results concern the m. glutaeus medius, the m. gracilis and the m. longissimus dorsi.
For routine detections it is suggested to examine the m. glutaeus medius. This muscle can be identified easily. Moreover its fibres are perpendicular to the cut surface, thus electrodes can be inserted in any direction, provided, that applied almost perpendicularly into the cut surface.
If a phase angle exceeding 10° is measured on the m. glutaeus medius it can be assumed, that the other muscles also show "negative" behaviour. For angles below 10° we recommend control measurements on other muscles (preferably m. longissimus dorsi). Of course, this is applicable also for positive results of the m. glutaeus medius if further information about the quota of affected muscles is desired. Since the procedure time is within a few seconds, even a high number of individual muscles can be examined without delay of routine slaughter line work.
According to closer discussion in /8/ the dielectric behaviour indicates rather distinct differences between structure characteristics of "positively" and "negatively" classified muscles. This can be supported by the extreme differences of phase angles and moreover, by the fact, that only a small quota of muscles show phase angles in the medium range close to 10°.

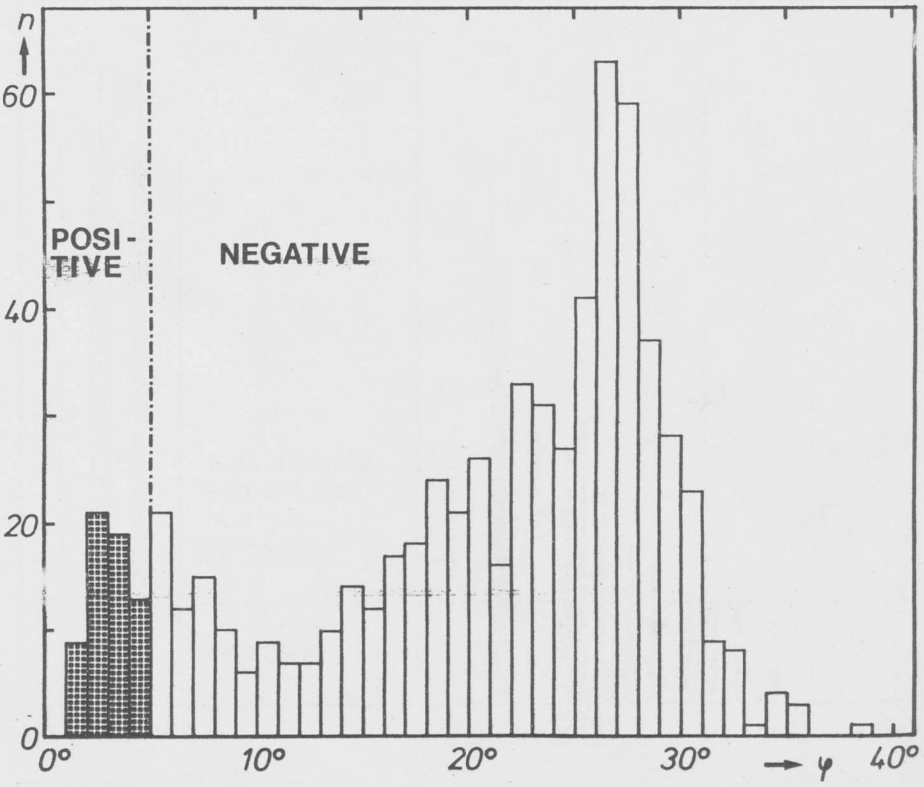

Fig.2 Frequency n of examined muscle versus phase angle φ (675 values)

This is demonstrated by Fig. 2 which shows the frequency of all electrically examined muscles versus φ. The majority of muscles - being also of unobjectionable appearance - show phase angles close to 25°; on the other hand, distinctly abnormal muscles show values below 5°. However, the frequency of φ - instead of forming a single Gaussian distribution curve - shows two Gaussian curves separated by a minimum close to 10°. Only few muscles fall into the range of 5° to 10°, a fact, which facilitates classification to a high extent.

Discussion

Measuring the phase angle φ enables rapid and simple detection of a muscle anomaly which can be assumed to be identical with the PSE-anomaly. Contrary to other objective parameters values of phase angle corresponding to "positive" or "negative" classification differ respectively from each other by about one power of ten. Thus, contrary to other methods, errors of measurement are almost without meaning. Due to extremely short procedure time a high number of individual muscles can be examined if necessary.

Acknowledgements

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