Acta vet. scand. 1991, *32*, 123–129.

Comparison of Different pH Measurement Methods in Meat

By *O. Mäki-Petäys, H. Korkeala, T. Alanko* and *O. Sorvettula*

Veterinary Department, Ministry of Agriculture and Forestry, Vuorikatu, and
Department of Food and Environmental Hygiene, College of Veterinary Medicine, Helsinki, and
Technical Research Centre of Finland, Computing Service, Espoo, Finland.

Mäki-Petäys, O., H. Korkeala, T. Alanko and O. Sorvettula: Comparison of different pH measurement methods in meat. Acta vet. scand. 1991, 32, 123–129. – The accuracy of portable pH meters and the nitrazine yellow method was compared with the reference method by determining the pH of 74 beef and 96 pork muscles. The pH was measured directly from the muscle. The results showed statistically significant differences ($p < 0.001$) between the different electrometric combinations. Combinations of portable pH meters with puncture electrodes gave systematically higher pH values than the reference method. These differences were not very large but they may be of practical significance. The use of a piercing cover on the electrode to help the insertion of the electrode into the meat is not recommended, since it may cause a rise in pH values. Electrometric methods were found to be more precise than the nitrazine yellow method. On the basis of these findings there still is a need of further harmonization of the methods used for pH measurement of meat.

meat quality; pH determination; electrometric methods; portable pH meters; nitrazine yellow method.

Introduction

The pH measurement of meat is widely used to assess the shelf life and quality of the carcass in meat inspection and in the meat industry for determining the different uses of the carcass. Dark cutting beef poses a specific problem. The high ultimate pH of DFD meat boosts bacterial growth and shortens storage life considerably. The determination of pH is essential in order to avoid the packaging of DFD meat and keep it off the fresh-meat market. This means rapid, consecutive and accurate measurements on the killing line.

The pH value of meat is also used in the international meat trade (*Anon.* 1982a). The increase and liberation of the meat trade also implies harmonization and rehabilitation of the methods used.

There are several works in which the authors have compared the precision of the different methods used in the determination of the pH of meat (*Prost* 1955, *Hofmann* 1968, Bager & Petersen 1983, *Dransfield et al.* 1983, *Korkeala et al.* 1986). *Korkeala et al.* (1986) found that the differences between the different electrodes used appeared to be greater than those due to the treatment of the meat samples. They used the direct puncture method, meat-water mixtures and muscle homogenates. *Prost* (1955) and *van Gils & van Logtestijn* (1965) considered electrometric determinations better than the various colorimetric and indicator methods. On the other hand *Honikel & Fischer* (1977) showed a very close relationship between pH values obtained with special indicator test strips and with glass electrode. There is

still a need for more reliable evaluation of the different methods.

The purpose of the present work is to evaluate the reliability of methods used in practice, since the pH measurement of meat before cutting and packaging is becoming more and more important. Two portable pH meters with puncture electrodes, which can be used on the killing line and which are used in Finland, were therefore compared to the combination *Korkeala et al.* (1986) found to give the average picture of the pH among the 7 electrometric methods they used. In addition, the colour indicator nitrazine yellow method was compared with the electrometric determinations. The study used beef and pork carcasses with low and high pH.

Materials and methods.

Sampling

Thirty-seven beef muscle samples from *M. triceps brachii caput longum* (MT) and *M. adductor* (MA) and 48 pork muscle samples from MT and MA were taken about 65 h (range 24–180 h) after slaughter. The pH of the samples was measured immediately after sampling.

Measurement of the pH

The pH of the samples was measured directly from the muscle with penetration electrodes (*Anon.* 1974, *Anon.* 1982).

The Knick 742 Microprocessor pH meter (Knick Elektronische Messgeräte Gmbh & Co, Berlin) with a Knick 6929 Thermocompensator probe and with a combined glass electrode Ingold 404-T (Dr. Ingold AG, Zurich, Switzerland) was used as the reference method. The ability of this method to determine pH is described by *Korkeala et al.* (1986).

The other methods used were combinations of portable pH meters and electrodes, as follows:

Knick 651 Portamess pH meter with combined glass electrode Ingold 404-T with piercing cover, referred to below as "method A".

WTW pH 90 pH meter (Wissenschaftlich-Technische Werkstätten GmbH, Federal Republic of Germany) with combined glass electrode Ingold LoT 406-M3, referred to below as "method B".

The pH of the samples was also measured with an aqueous solution of the nitrazine yellow indicator (0.01 %) test (*Anon.* 1955, *Schönberg & Zietzschmann* 1958).

Each pH measurement was read and recorded to the nearest 0,01 pH units electrometrically and to 0,1 pH units with nitrazine yellow. The meat used for the measurement was free of visible fat and connective tissue.

The samples were measured chilled. The measurements were carried out in the laboratory (22°C) at least twice with all electrodes and once with nitrazine yellow. The electrodes were cleaned (*Anon.* 1974) after each measurement and the pH meter calibration was checked according to the instructions of the manufacturer with buffer solutions with pH 4 and 7 (Dr. W. Ingold AG) at regular intervals. The temperature of the buffer solutions was 5°C.

Statistical methods

The ordinary pH scale, rather than the hydrogen ion concentration scale (H+-scale) sometimes recommended in the literature (cf. *Murphy* 1982), was used as in *Korkeala et al.* (1986).

The arithmetic mean of the 2 replicate pH-values was used as the basic unit for all other calculations except in the case of nitrazine yellow, where only 1 measurement was available.

Table 1. Means and standard deviations of pH values of muscle samples measured with different methods.

Muscle samples	N	Method[a] Reference	A	B	Nitraz.
All	168	5.84 ± 0.40	6.11 ± 0.38	6.03 ± 0.37	–
Beef	74	5.74 ± 0.39	6.00 ± 0.35	5.94 ± 0.36	–
Pork	94	5.92 ± 0.39	6.20 ± 0.39	6.10 ± 0.36	–
MT[b]	84	5.93 ± 0.41	6.22 ± 0.38	6.11 ± 0.38	–
MA[c]	84	5.74 ± 0.37	6.01 ± 0.35	5.94 ± 0.34	–
pH < 6.00	118	5.62 ± 0.19	5.91 ± 0.18	5.82 ± 0.16	–
ph > 6.00	50	6.35 ± 0.29	6.59 ± 0.28	6.50 ± 0.28	6.5 ± 0.2

[a] See Materials and Methods.
[b] MT = Musculus triceps brachii caput longum.
[c] MA = Musculus adductor.

Statistical comparison of the 3 pH-measurement methods was performed using repeated-measures-model analysis of variance (*Winer* 1971). The differences between the reference method and methods A and B were tested by pre-defined contrasts in the repeated measures analysis of variance. An ad hoc cut-off rule was used to divide the samples into 2 groups – the "high" pH-group and the "low" pH-group – as follows: If the average over the 3 pH-measurement methods of a muscle sample was above 6.0 it was included in the group "pH above 6.00", if the average was lower than or equal to 6.00 it was included in the group "pH 6.00 or below". Analysis of variance was then performed for the second group separately, with nitrazine yellow as a fourth method included in the "pH above 6.0" samples.

All calculations were performed using the SAS statistical package on a microcomputer.

Results

The means and standard deviations of the pH-measurement methods for the 4 types of methods and the different muscle sample groups are presented in Table 1. The results of the F-tests for the equality of means are shown in Table 2. Results showing statistically significant differences between the reference method and other methods are also presented in Table 2.

Table 2. Significance of differences between pH measurement methods and the reference method. The F-values refer to pre-defined contrasts in repeated measures analysis of variance.

Method[a]	F-value	
Method A	365.35	$p < 0.0001$
Method B	346.17	$p < 0.0001$
Nitrazine yellow method	8.52	$p < 0.01$

[a] See Materials and Methods.

Table 3. Classification of samples into pH classes by different methods (in per cent).

Method[a]	pH > 6.00	> 6.20	> 6.50
Reference method	27.4	20.2	10.7
Method A	50.6	32.7	16.7
Method B	40.5	27.4	14.9
Nitrazine yellow method	39.9	28.6	13.1

[a] See Materials and Methods.

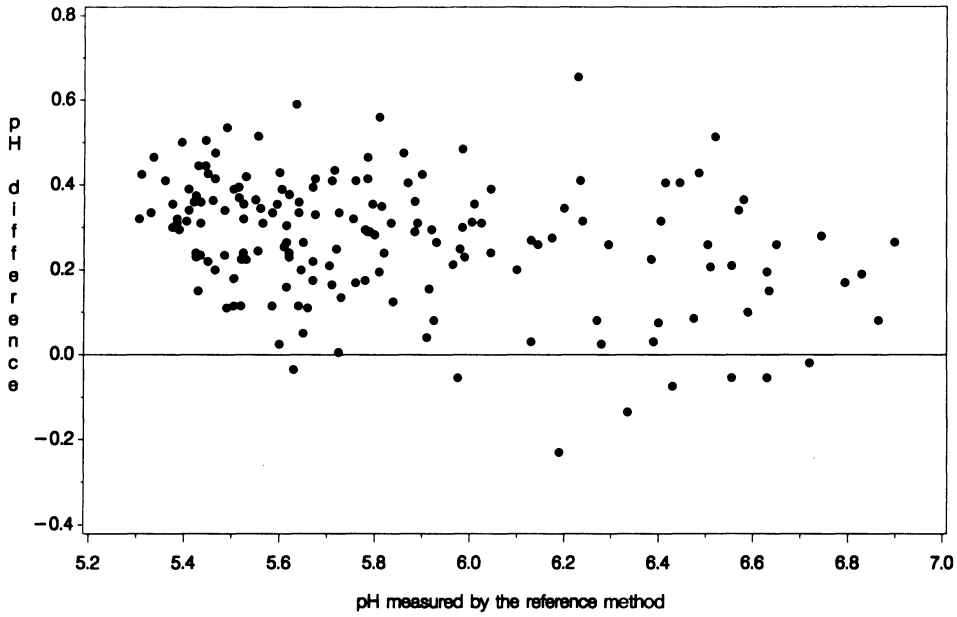

Figure 1. Scatter diagram of pH difference between method A and the reference method.

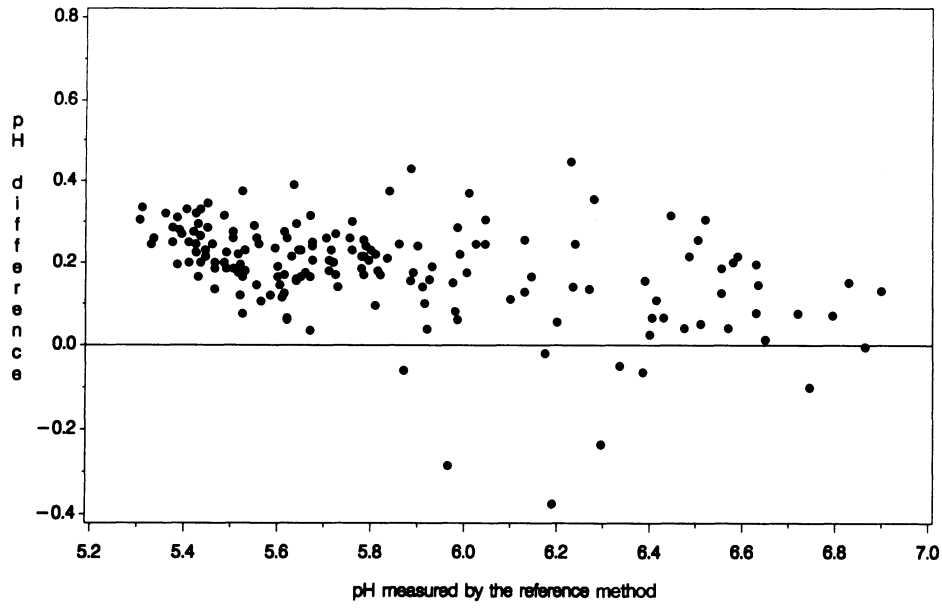

Figure 2. Scatter diagram of pH difference between method B and the reference method.

Table 3 and Figures 1 and 2 illustrate the magnitude and nature of these differences. In Table 3 the percentage of muscle samples classified into particular pH-groups by a method is reported. In Fig. 1 the difference between method A and the reference method and in Fig. 2 the difference between the reference method and method B is plotted against the pH-level of the sample measured by the reference method. Figs. 1 and 2 show both that the differences are rather systematically positive and that they do not vary markedly along the pH-scale.

The correlation coefficient between nitrazine yellow and the reference method was 0.66.

Discussion

All the F-tests given in Table 2 reveal that there are statistically significant differences between the reference method and the other pH-measurements methods.

The distribution of the samples into different pH classes seems to depend on the method used (Table 3). In the case of method A the proportion of samples with high pH values are greater than by the other methods. Comparing method A and the reference method, which gave the highest and lowest mean of the pH (Table 1), we find that method A gives systematically higher pH values than the reference method (Fig. 1). The maximum value of the difference between method A and the reference method was 0.65 and the mean of the difference was 0.27. This difference could be due to the piercing cover used on the electrode. Even if the 3 diaphragms of the electrode were in free contact with the meat, the cover might diminish the strength of the contact. Although with puncture measurements there is always the risk of breaking the electrode shaft on insertion, the use of a piercing cover on the electrode nevertheless seems disadvantageous. Comparing method B and reference method, we find that method B too gives higher pH values than the reference method (Fig. 2). The mean of the difference was 0.19. We also find that the difference does not depend on the pH of the sample. Differences like these may have a practical meaning.

Errors in the pH determination of meat may also be harmful in meat inspection. The estimation of the pH of meat is of value in the judgement of borderline cases, particularly of emergency-slaughtered animals, since it indicates whether or not the meat will possess adequate durability (*Gracey* 1986). In addition the pH determination is important in the interpretation of the boiling test. *Korkeala et al.* (1988) found that in beef the odour scores remain steady for samples with a pH value under 6,2 and start to increase rapidly in higher values.

In chosing carcasses for different uses on the basis of the pH value of meat, are the measurements to be made on the killing line or in the chilling room. Some authors have stressed that the most accurate results are obtained by the electrometric method using minced meat, juice or homogenates (*Hofmann* 1988). *Korkeala et al.* (1986) reported the differences between electrodes to be greater than the differences due to the presentation of the meat samples. However, only direct puncture measurements are useful on the killing line, where it is necessary to make a large number of measurements in rapid sequence. Portable pH meters are the only way to measure the pH of meat electrometrically on the killing line or in the chilling room.

Although nitrazine yellow has a high correlation with the reference method (0.66) it is not suitable for common use in meat technology. *Van Gils & van Logtestijn* (1967) also stressed that nitrazine yellow is not

suitable for scientific investigation. The method may, however, in some cases be useful in field conditions where electrometrical methods are not available.

Our results show that the combinations of different electrodes and pH meters by which the measurement is carried out behave differently. However, we cannot say with certainty which of the methods gives the best picture of the real pH of the meat (*Korkeala et al.* 1986). It therefore seems important to attempt further research of the reliability of methods usable in practice. The use of a piercing cover on the electrode should be avoided. When the pH value is used in the evaluation of meat quality, the recommendations for the pH determination should be included, due to great differences in results obtained by different combinations of electrodes and pH meters.

References

Anonymous: Join FAO/WHO expert committee on meat hygiene. Wld. Hlth. Org. tech. Rep. Ser. No. 99, World Health Organisation, Geneva 1955.

Anonymous: Meat and meat products. Measurement of pH (reference method) ISO 2917, International Organisation for Standardisation, Geneva 1974.

Anonymous: Mindestanforderungen an Schlacht-, Zerlege- und Verarbeitungsbetriebe sowie Kühlhäuser, die Fleisch oder Fleischwaren nach der Schweiz exportieren. (Minimum requirements for the approval of slaughterhouses, cutting and processing plants, and cold stores which export meat or meat products to Switzerland). Bundesamt für Veterinärwesen (Federal Veterinary Office), Liebefeld 1982a.

Anonymous: Lihan pH:n mittaaminen. (Determination of pH in meat). Circular No. 201, Veterinary Department, Ministry of Agriculture and Forestry, Helsinki 1982b.

Bager F, Petersen GV: The Relative Precision of Different Methods of Measuring pH in Carcass Muscles. Nord. Vet.-Med. 1983, *35,* 86–90.

Dransfield E, Casey JC, Boccard R, Touraille C, Buchter l, Hood DE, Joseph RL, Schon I, Casteels M, Cosentino E, Tinbergen BJ: Comparison of Chemical Composition of Meat Determined at Eight Laboratories. Meat Sci. 1983, *8,* 79–92.

van Gils J HJ, van Logtestijn JG: Die pH-Messung des Fleisches-Hilfsmethode zur Beurteilung des Fleisches von Schlachttieren. (Measurement of pH in meat – and aid in the judgement of meat of slaughtered animals). Arch. Lebensmittelhyg. 1967, *18,* 49–56.

Gracey JF: Meat Hygiene. Bailliére Tindall, London 1986, 238.

Hofmann K: Untersuchung der Zuverlässigkeit der pH-Wert-Messung an Fleisch mit Hilfe der Glaselektrode. (Investigations into the reliability of pH-value measurement in meat using a glass electrode). Fleischwirtsch. 1968, *48,* 317–322.

Hofmann K: pH, a quality criterion for meat. Fleischwirtsch. 1988, *68,* 67–70.

Honikel KO, Fischer C: Vergleichende Messung des pH-Werts mit Glaselektrode und spezialindikatorstäbchen bei Rindfleisch. (Comparative pH measurements in muscles of beef using a glass electrode and special indicator test strips). Fleischwirtsch. 1977, *57,* 2175–2177.

Korkeala H, Mäki-Petäys O, Alanko T, Sorvettula O: Determination of pH in meat. Meat Sci. 1986, *18,* 121–132.

Korkeala H, Alanko T, Mäki-Petäys O, Sorvettula O: The effect of the pH of meat on the boiling test. Acta vet. scand. 1988, *29,* 15–22.

Murphy MR: Analyzing and Presenting pH Data. J. Dairy Sci. 1982, *65,* 161–163.

Prost E: Studies on Determinations of pH of meat. Medycyna Wet. 1955, *11,* 142–147.

Schönberg F, Zietzschman MO: Die Ausführung der tierärztlichen Fleischuntersuchung. (The Practice of Veterinary Meat Inspection). Verlag Paul Parey, Berlin 1958, 160.

Winer BJ: Statistical principles in experimental design. 2nd edn. McGraw-Hill, New York 1971, 261–308.

Sammanfattning

Jämförelse mellan olika pH mätningsmetoder av kött.

Noggrannheten av portabla pH mätare och nitrazingult jämfördes med en referensmetod genom att bestämma pH-värdet av muskelprover på 74 nöt och 96 svin. pH-värdet mättes direkt från muskeln. Resultatet visar statistiskt märkbara skillnader ($p < 0.001$) mellan de olika elektrometriska kombinationerna. Kombinationer av portabla pH mätare med penetrerande elektroder gav systematiskt högre pH-värden än referensmetoden. Dessa skillnader var inte stora men de kan ha praktisk betydelse. Användningen av penetrerande hylsa på elektroden för att underlätta införandet av elektroden i köttet är inte att rekommendera, emedan den förorsakar en förhöjning av pH-värdet. De elektrometriska metoderna befanns vara exaktare än nitrazingult. Resultaten av undersökningen utvisar att det fortfarande finns ett behov att harmoniera metoderna som används för att mäta köttets pH.

(Received February 7, 1990, accepted February 9, 1990).

Reprints may be requested from: H. Korkeala, College of Veterinary Medicine, Department of Food and Environmental Hygiene, P. O. Box 6, SF-00551 Helsinki, Finland.