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Technologies for Detecting PSE in Pork

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Contents

TECHNOLOGIES FOR DETECTING PSE IN PORK

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SUMMARY

The ability of a single, on-line measurement to predict the quality status of an entire muscle or even of a whole carcass was investigated. Variation between pork muscles for on-line measurements of pH, conductivity and colour was evaluated. Intermuscular variation was detected at 24h *postmortem* with higher pH and conductivity values in the topside (*M. semimembranosus*) than the striploin (*M. longissimus thoracis et lumborum*). Correlations showed that a relationship exists between the muscles (r = 0.46-0.88, $p<0.05$) at 45min and 3h *postmortem*. The location within the topside or the striploin at which the measurements were taken did not influence the result. Shackling did not introduce a significant variation between sides for pH, conductivity and colour values up to 24h *postmortem*, showing measurements could be taken on either side of the carcass.

The relationship between objective (instrumental) colour measurements and subjective (visual) measurements of pork colour was established. This work was carried out in an attempt to provide the pork processing industry with instrumental quality specifications for rejecting or accepting pork topsides for further processing. A strong relationship was found between visually assessed meat colour and both instrumental L* (r = - 0.706) and percent reflectance (r = 0.711) values. CIE L* values above 57 and percent reflectance values below 43% correctly classified 75% of the 'pale' topsides. CIE L* values below 53 and percent reflectance values above 53% correctly classified 75% of the 'good' topsides. The topsides were processed and the effect of 'pale' and 'good' pork on the quality of the cooked hams was assessed. Differences were found in ham colour as measured by CIE L* and b* values ($p<0.001$), percent reflectance ($p<0.001$), moisture content ($p<0.001$), water-holding capacity ($p<0.05$) and textural components ($p<0.05$).

Ideally, early *postmortem* on-line objective measurements need to be developed which can predict the quality attributes of the end product. The focus of this work was to monitor the ability of pH, conductivity and colour measurements in fresh pork to predict the quality of cooked ham. On-line pH and conductivity measurements correlated with percent reflectance, moisture

content and water-holding capacity of cooked ham products. It was concluded that objective colour measurements taken on the striploin and topside muscles after boning out may be useful in the prediction of water-holding capacity of the cooked hams.

INTRODUCTION

Despite some improvements over recent decades, the incidence of PSE (pale, soft, exudative) meat in the Irish pork industry remains a serious economic problem for producers, processors and retailers alike. A number of factors contribute to the quality status of a pork carcass including genetics, nutrition, seasonality, handling procedures on the farm and during transit to the packing plant, method of stunning, method of dehairing, and method and time of chilling after slaughter. The PSE condition is characterised by a rapid drop in meat pH after slaughter and a low final pH, resulting in meat which is pale in colour, has a soft texture and is exudative or watery. Colour is one of the most important quality attributes as it influences the attractiveness of pork at purchase. Consumers avoid PSE pork in the fresh state because of its unattractive appearance (Kauffman *et al.*, 1992; Joo *et al.*, 1995; O'Neill *et al.*, 2003). Meat processors reject it because, when processed, it usually results in an insipid, watery product with little cohesiveness (Townsend *et al.*, 1980; Wirth, 1986; Honkavaara, 1988). In a study by O'Neill *et al.* (2003), cooked hams manufactured from PSE pork had an estimated financial loss of 50% compared to hams manufactured from normal pork.

Pork plants must be able to assess the quality status of pigmeat accurately, quickly and economically for sorting prior to processing or merchandising. To accomplish this, they need optimised procedures to assess quality variations.

Previous studies at The National Food Centre (Mullen *et al.*, 2000; Walsh *et al.*, 1997 & 1998) have shown that pH, electrical conductivity and colour measurements are useful in the early *postmortem* on-line detection of pork quality. These findings are substantiated by many others - Swatland, 1995; Dvořák *et al.*, 2001; Lee *et al.*, 2000; Berg, 2000; Van Oeckel *et al.*, 1999.

OPTIMAL ON-LINE MEASUREMENT PROCEDURES

There are many points on a carcass at which industry personnel can take readings with hand-held probes for pH, conductivity and colour. Predicting meat quality from a single on-line measurement has great commercial potential if measurement at one site can predict the status of the whole muscle or even of the entire carcass. To identify the optimum site(s) for measurements, the following factors must be taken into consideration. The sample site needs to be easily accessible. Information is required on the relationship between readings taken on the major muscles, for example the topside muscle and the striploin. Within a particular muscle, such as the striploin, the influence of the location of a measurement along the length of the muscle needs to be understood. Variation can arise between carcass sides when pigs are shackled by one ham and the other is free to kick (Gregory, 2000). Therefore, differences in measurements between sides of the carcass need to be evaluated.

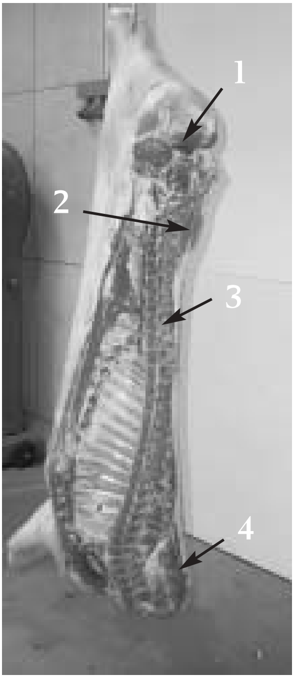
To develop a procedure for on-line measurements, we determined: the effect of measurement site on the carcass on pH, conductivity and colour readings at 45min, 3h and 24h *postmortem*; the influence of measurement location within a muscle on values obtained; the impact of shackling on the pH, conductivity and colour of pork.

Approach: Twenty-nine Swedish Landrace pigs were slaughtered at the research abattoir over a 4 week period. pH, conductivity and colour measurements were recorded at 45min, 3h and 24h *postmortem*. Electrical measurements were recorded on both the left and right halves of pig carcasses

Measuring pH of pork topside muscle using an Orion pH meter (Model 250 A) with glass electrode (Amagruss Electrodes Ltd.).

at thee sites within the topside and in the caudal, medial and cranial sections of the striploin.

Surface colour measurements were taken from the right and left hand sides at three sites exposed when the carcass was split through the aitch bone (*symphysis pubis*); the surface of the topside (*M. semimembranosus)*, the oyster muscle (*M. gluteus medius*) and at the top of the neck (*M. biventer cervicis* & *M. splenius*). On pork sides, colour was assessed on the CIE L*a*b* scale, as a percentage of red light reflectance using Japanese pork colour scores.



Locations on a pork carcass at which pH, conductivity and colour measurements were recorded.
1 = topside (M. semimembranosus)
2 = oyster muscle (M. gluteus medius)
3 = loin (M. longissimus dorsi)
4 = the neck (M. biventer cervicis & M. splenius)

Outcome: Values obtained for pH and conductivity measurements within each muscle were not affected by the location within that muscle at which the probe was inserted. This was true for pH and conductivity measurements taken at all three time points. These findings indicate that a single on-line measurement taken on the striploin or topside may be used to accurately predict pH and electrical properties of the whole muscle. The topside had higher ultimate pH and conductivity values than the striploin at 24h *postmortem;* this was anticipated due to the different functions of the muscles. Pearson correlation coefficients were used to examine the relationship between the striploin and topside. A relationship was observed between muscles for pH and conductivity measurements at 45min and 3h *postmortem* (Table 1).

No significant colour differences were recorded between the topside and oyster muscles. However, the neck muscles were redder (higher a* values) and darker in colour (lower L* values, higher percent reflectance) ($p<0.001$). No signficant differences were observed, for colour, pH and conductivity measurements when the left-hand side of the carcass was compared to the right-hand side (topside and striploin). This indicates that shackling one side of the carcass only does not alter the colour, pH or conductivity values in these muscles.

Measuring conductivity on carcasses using a Pork Quality Meter (PQM, Intek GmbH) gives information about the quality of the pork.

Table 1: Correlation coefficients showing the relationship between measurements (pH and conductivity) taken on the striploin and those taken on the topside muscles. The relationship between muscles within the left and right sides of pork carcasses at three time points *postmortem* are presented.

	Left side of carcass			Right side of carcass		
	45min	3h	24h	45min	3h	24h
pH	0.47 **	0.55 *	ns	0.46 **	0.65 **	ns
Conductivity	0.64 ***	0.88 ***	ns	0.76 ***	0.78 ***	ns

Level of significance ***P<0.001 **P<0.01 *P<0.05 ns non significant.

INDEPENDENT THESHOLD VALUES FOR DETECTION OF QUALITY STATUS OF PORK TOPSIDE MUSCLES

At present it is difficult for the ham processing industry to determine the technological quality of pork meat prior to the production of cooked ham. Recent problems experienced by ham producers have centered on the quality of the raw material, namely the topside muscles, *Mm. semimembranosus* and *adductor*. As visual assessment is the primary, and often the only, method used by these producers, they require objective methods of assessing the quality of raw material prior to processing. Providing quality specifications for raw material will give a firm basis for either rejecting meat or for processing it differently from normal, good quality meat. In the past, work in this area has tended to focus on early *postmortem* pH and electrical measurements on other muscles throughout the carcass. However, as secondary processors generally receive raw material just prior to ham production, early *postmortem* assessment of the quality status of the meat is out of their reach. Following discussions with the industry, the present study was conducted to establish the relationship between objective colour measurements (percent reflectance and CIE L* coordinates) and subjective (visual) methods of assessing pork quality prior to processing into ham. Following processing, PSE pork poses many problems with colour and sliceability of the final product being of major concern to ham producers. Meat quality comparisons were therefore carried out on hams produced following visual classification.

Approach: Pork topsides (consisting of both *Mm. semimembranosus* and *adductor*) were purchased by a large ham producing company for further processing. Trained industry personnel, experienced in the assessment of pork, visually assessed topsides as being 'pale' (n=489) or 'good' (n=625) in colour. The paleness tended to be more severe in the middle part of the topside (*M. adductor*) which is located deep in the hind leg, close to the femur. Objective colour measurements (CIE L* values and percentage red-light reflectance) were determined on the surface of topsides in this region. The CIE L* co-ordinate was recorded using a portable HunterLab Miniscan XE (Hunter Associates Laboratory, 11491 Sunset Hills Road, Reston, VA 20190) and percent reflectance was measured using an Optostar Intelligent Colour Gauger (SFK Technology A/S, Transformervej 9, 2730 Herlev, Denmark). The topsides were processed and the resulting ham logs were labelled 'pale' (n=45) or 'good' (n=57) depending on the raw batch from which they were produced. Comparisons between the sliceability, colour, water-holding capacity and instrumental texture components of 'good' and 'pale' ham products were then determined. Pearson correlation coefficients were used to examine the relationship between objective (CIE L*, percent reflectance) and subjective (visual) assessment of raw meat quality.

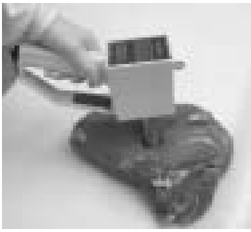
Outcome: Significant colour (CIE L*, a* and percent reflectance) differences ($p<0.001$) were observed between 'good' and 'pale' topsides. Pearsons correlation coefficients also confirmed a strong relationship ($p<0.001$) between visually-assessed meat and both L* ($r = -0.706$) and percent reflectance ($r = 0.711$) values. Figure 1 shows cut-off values at which CIE L* and percent reflectance correctly classified 75% of the 'good' and 'pale' topsides. CIE L* values above 57 and percent reflectance values

Topside visually assessed by experienced industry personnel

'good' = 601

'poor' n=465

Subjective colour assessment carried out with CIE L* & percent reflectance



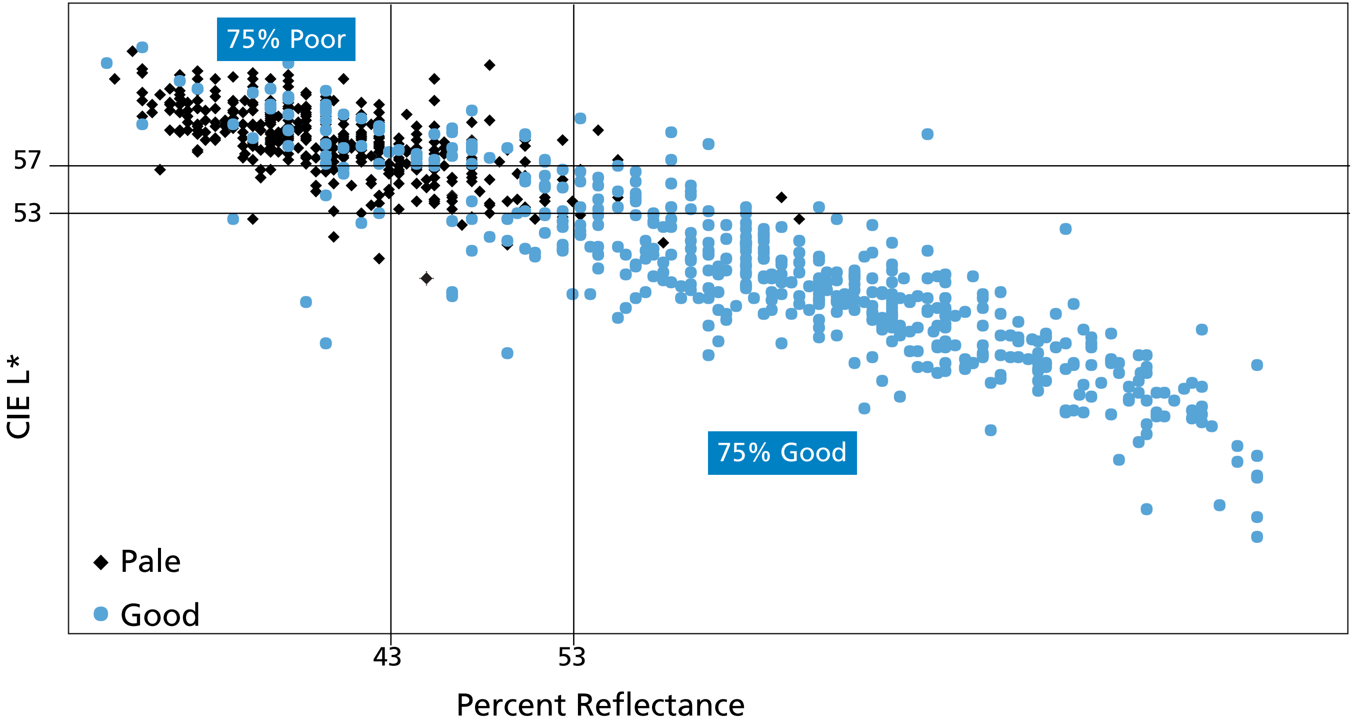
Percent reflectance using Optostar Intelligent meat Colour Gauge (SFK Technology)

CIE L using Miniscan XE (Hunter Associates Laboratory).*

Hams produced using 'good' and 'poor' muscles

below 43% correctly classified 75% of the 'pale' muscles. CIE L* values below 53 and percent reflectance values above 53% correctly classified 75% of the 'good' topsides. [Note:- 'r' = correlation coefficient; the closer r is to ±1, the stronger the relationship between L* or percent reflectance and visual assessment].

Figure 1: Cut off values at which CIE L* and percent reflectance correctly classified 75% of the visually-classified 'good' and 75% of the 'poor' pork topsides.



Hams produced from ‘good’ topsides had significantly different CIE L*, b* and percent reflectance values compared to those produced from ‘pale’ topsides (Table 2). A higher water-holding capacity ($p<0.05$) and moisture content ($p<0.001$) was observed in hams processed using the ‘pale’ muscles. The textural characteristics of the hams were different ($p<0.05$) and those produced using ‘good’ meat had greater cohesiveness, chewiness, gumminess and springiness. The use of ‘pale’ muscles in ham production reduced the sliceability ($p<0.01$) of the end product.

Table 2: Quality measurements of hams processed using pork topsides that were visually assessed as ‘pale’ or ‘good’.

	‘Pale’ pork		‘Good’ pork		
	Mean	± SD	Mean	± SD	P value
CIE L*	67.05	3.46	65.04	3.74	***
CIE a*	10.62	1.43	10.57	1.42	ns
CIE b*	10.99	0.69	9.58	0.87	***
% Reflectance	30	6.5	35	7.2	***
Sliceability (%)	62.4	6.5	66.8	9.3	**
Hardness	112	24	119	31	ns
Springiness	5.87	0.67	6.17	0.98	**
Cohesiveness	0.43	0.06	0.46	0.11	*
Gumminess	48.4	10.7	52.3	12.7	*
Chewiness	282	76	322	103	***
% Moisture	68.2	0.97	69.9	0.87	***
% WHC[1]	96.5	0.4	97.0	0.55	*

Significant differences: ***P<0.001, **P<0.01, *P<0.05, ns = not significant

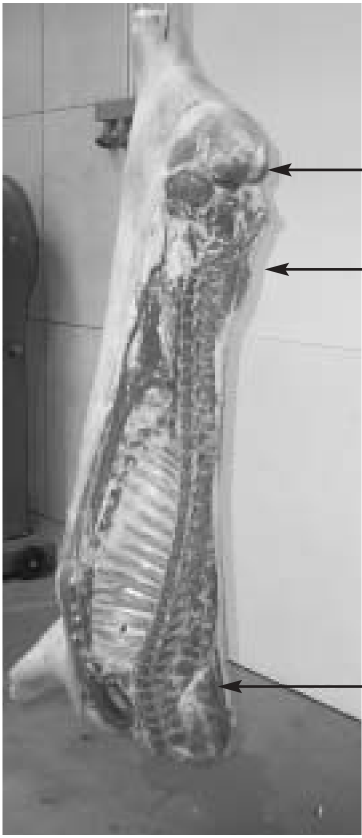
[1] Water-holding capacity.

PREDICTION OF COOKED HAM QUALITY USING EARLY *POSTMORTEM* ON-LINE MEASUREMENTS

There is a technological disadvantage in using PSE pork in processed meat products. Its use has been reported to cause low yields, pale colour, crumbly texture and poor consistency. Improvements in the handling of pigs before slaughter and in carcass handling are known to reduce the incidence of PSE. Additionally, quality controls may be applied so that only the most suitable hams are chosen for processing. Ideally, early *postmortem* objective measurements, which can predict the quality attributes of cooked hams, need to be developed for pork. The focus of this trial was to monitor the ability of early *postmortem* (up to 24h *postmortem*) on-line measurements to predict the quality of the cooked product.

Approach: This trial was conducted in a commercial slaughtering plant. Six normal and 7 PSE carcasses were selected on the basis of pH_{45min} readings from the striploin. Further pH measurements were taken between the 3rd and 4th rib of the striploin at 2, 3, 4, 5, 6 and 24h *postmortem*. pH was also recorded in the topside (*M. semimembranosus*) at 3, 6 and 24h *postmortem*. Electrical conductivity was determined in the striploin at 1, 3, 6 and 24h *postmortem* and in the topside at the three latter timepoints.

CIE L*a*b* and percent reflectance values were measured at three sites on the surface of the split carcass; the topside, the oyster muscle and at the top of the neck (*M. biventer cervicis* & *M. splenius*). CIE L*a*b* and percent reflectance values were recorded at 3, 6 and 24h *postmortem*. When the final 24h on-line measurements had been recorded, the carcasses were removed to a boning hall where the striploin and topside muscles were excised. CIE L*a*b*, percent reflectance and Japanese colour scores were then recorded on the exposed surfaces of the striploin and topside muscles. Hams were prepared using current commercial guidelines and the following quality attributes were assessed: cookloss, sliceability, colour, moisture content, water-holding capacity and instrumental textural components.



Carcass locations at which surface colour measurements were recorded.

Outcome: Statistically significant relationships were observed between several early *postmortem* pH and conductivity measurements and the moisture, water-holding capacity and percent reflectance of cooked hams (Table 3). Results also indicated that that CIE L* ($p<0.05$) and percent reflectance ($p<0.01$) measurements taken from boned-out topsides and striploins at 24h *postmortem*, could be used to predict the water-holding capacity of the cooked hams. Japanese colour scores taken from the striploin at the same time were correlated to both the moisture content and the water-holding capacity of the hams (Table 3).

Table 3: Pearson correlation coefficients (r) between early *postmortem* measurements on pork carcasses and the moisture content, water-holding capacity (WHC) and percent reflectance (% R) of cooked ham products.

	Muscle	Time	WHC	Moisture	% R
pH	Striploin	5h	-0.56*	0.61*	-
	Striploin	6h	-0.67*	-	-
	Topside	3h	-	0.65*	-0.72**
	Topside	6h	-	-	-0.66*
	Topside	24h	-0.58*	0.57*	-
Conductivity	Striploin	1h	-	-0.61*	-
	Striploin	3h	-	-0.57*	-
	Striploin	6h	-	-0.56*	-
	Striploin	24h	0.67*	-	-
	Topside	3h	-	-	0.65*
	Topside	6h	-	-	0.61*
	Topside	24h	-	-	0.61*
CIE L*	Striploin	24h	0.75** [b]	-	-
	Topside	24h	0.55* [b]	-	-
% R	Striploin	24h	-0.72** [b]	-	-
	Topside	24h	-0.70** [b]	-	-
JCS	Striploin	24h	-0.66* [b]	0.56* [b]	-

Levels of significance: ***P<0.001, **P<0.01, *P<0.05,

[b] Measurements taken after muscles were boned out.

r = correlation coefficient.

JCS = Japanese colour score blocks.

The hardness, chewiness and gumminess of the hams were correlated (p<0.01) with CIE L* measurements in the *M. semimembranosus* at 6h *postmortem* (Table 4). Strong, but less significant (p<0.05), correlation coefficients were also observed between these parameters and the percent reflectance of the neck muscle at 24h *postmortem* (Table 4).

Table 4: Simple correlation coefficients between textural components of cooked hams and on-line CIE L* and percent reflectance measurements in fresh pork.

	Muscle	Time	Hardness	Chewiness	Gumminess
CIE L*	Topside	6h	-0.76**	-0.73**	-0.75**
Percent reflectance	Neck	24h	-0.63*	-0.55*	-0.59*

Levels of significance: **P<0.01, *P<0.05.

r = correlation coefficient, the closer r is to ±1, the stronger the relationship between L* or percent reflectance and textural components.

CONCLUSIONS

- Instrumental measurements can be used to segregate pale pork topsides prior to processing into hams.
- The quality of the final ham product can be predicted by subjective (visual) and objective (instrumental) colour measurements on pork topsides.
- Instrumental colour measurements taken from boned-out striploin and topside muscles at 24h postmortem can be used to predict the water-holding capacity of the resulting cooked hams.
- Chilled pork carcasses at 24h *postmortem* have higher pH and conductivity values in the topside muscle than in the striploin. However, a relationship was observed between these properties of the striploin and topside at 45min and 3h *postmortem*, indicating that measurements taken in the striploin may be used to predict the quality of the topside and *vice versa*.
- The location within the striploin or topside at which pH and conductivity were measured did not affect the reading; this suggests that a single measurement may be used to predict the overall value for a given muscle.

- Shackling does not have a significant effect on pH, conductivity and colour measurements taken on striploin or topside up to 24h *postmortem*. This indicates that a measurement on one side of the carcass may be used as an indication of the same muscle on the other side of the carcass.

RECOMMENDATIONS TO INDUSTRY

Methods for predicting meat quality are needed during the early *postmortem* period before carcasses enter the boning hall and are also required prior to secondary processing of the meat. Two measurements of colour, namely reflectance and CIE L*, have displayed potential as predictors of pork topside quality prior to the production of hams, providing objective threshold values for acceptance or rejection of the raw material. Pork reflectance values may be measured using an Optostar Intelligent Colour Gauger (SFK Technology A/S, Transformervej 9, 2730 Herlev, Denmark) while the CIE L* value of colour may be determined using a portable HunterLab Miniscan XE (Hunter Associates Laboratory, 11491 Sunset Hills Road, Reston, VA 20190). Both instruments are portable for efficient on-line use. They only require recalibration after 4 hours of constant use and non-technical staff can be easily trained in their operation. Both these colourimeters performed well as objective methods of segregating pale from normal pork topsides and show potential for industrial application. The cost of the meters varies, with the Optostar retailing at less than €3000 and the Hunterlab colourimeter at around €6000.

While the more conventional method for predicting pork quality during the early *postmortem* period is the measurement of pH at 45 min after slaughter, it is not always reliable. Other instruments may be easier to operate in terms of calibration method, frequency of calibration, drift during use and combination of probe and meter. For example, several meters have been designed to measure electrical conductivity by inserting a single unit, two-pronged probe, into the carcass. Examples include the Pork Quality Meter (PQM, Intek GmbH, Industriestrasse 9, D-86551 Aichach, Germany) and the NWK LT K21 (NWK – THEIN GmbH, Landsberf, Germany). It has been suggested that measurements of electrical conductivity up to 24 hours *postmortem* may provide a useful method of determining pork quality. In some cases combining ultimate pH with conductivity increases the ability to predict quality. Conductivity meters are relatively robust and easy to use; care, however, is required to ensure the prongs are not bent and that the orientation of the probe is standardised while reading. Conductivity meters may retail at less than €3000 while pH meters tend to be €1000 and under.

When using readings on individual muscles to predict meat quality in a carcass, it is necessary to have an appreciation of inherent variability associated with the measurements. Variation may be introduced by many factors including the type of probe used, the calibration method, temperature of the sample (especially in the case of pH) and the position along the muscle or side of a carcass at which the reading is taken. Although the location within the topside or striploin does not influence the measured pH, conductivity or colour (measured on the cut surface of a pork chop after 3 hours exposure to air), different muscles can be expected to have different values for electrical and colour measurements. Measurements taken along the striploin may be used to predict those on the topside – however, if the quality of other muscles needs to be predicted, their relationship with the striploin must first be established. Shackling does not have a significant effect on the values investigated so on-line measurements taken from the topside or striploin muscle on one side may be used as an indication of the same muscle on the other side of the carcass.

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