Objectively Predicting Ultimate Quality of Post-Rigor Pork Musculature: II. Practical Classification Method on the Cutting-Line

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ABSTRACT : To investigate the practical assessing method of pork quality, 302 carcasses were selected randomly to represent commercial conditions and were probed at 24 hr postmortem (PM) by Danish Meat Quality Marbling (MQM), Hennessy Grading Probe (HGP), Sensoptic Resistance Probe (SRP) and NWK pH-K21 meter (NpH). Also, filter paper wetness (FPW), lightness (L*), ultimate pH (pHu), subjective color (SC), firmness/wetness (SF) and marbling scores (SM) were recorded. Each carcass was categorized as either PSE (pale, soft and exudative), RSE (Reddish-pink, soft and exudative), RFN (reddish-pink, firm and non-exudative) or DFD (dark, firm and dry). When discriminant analysis was used to sort carcasses into four quality groups the highest proportion of correct classes was 65% by HGP, 60% by MQM, 52% by NpH and 32% by SRP. When independent variables were combined to sort carcasses into groups the success was only 67%. When RSE and RFN groups were merged so that there were only three groups (PSE, RSE+RFN, DFD) differentiating by color MQM was able to sort the same set of data into the new set of three groups with 80% accuracy. The proportions of correct classifications for HGP, NpH and SRP were 75%, 61% and 35% respectively. There was a decline in predication accuracy when only two groups, exudative (PSE and RES) and non exudative (RFN and DFD) were sorted. However, when two groups designated PSE and non-PSE (RSE, RFN and DFD) were sorted then the proportion of correct classification by MQM, HGP, SRP and NpH were 87%, 81%, 71% and 66% respectively. Combinations of variables only increased the prediction accuracy by 1 or 2% over prediction by MQM alone. When the data was sorted into three marbling groups based on SM this was not well predicted by any of the probe measurements. The best prediction accuracy was 72% by a combination of MQM and NpH. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 1 : 77-85)*

Key Words : Pork Quality, PSE, RSE, Marbling, Objective Prediction

INTRODUCTION

At present, significant variations occur between pork carcasses for both the yield of muscle and the quality of that muscle. The lack of concern for meat quality and the industry's inability to objectively measure it in pork carcass grading have been several reasons why there has been an increase in poor quality. There are several practical problems associated with assessing pork muscle quality postmortem. The variations of color or water-holding capacity (WHC) in porcine muscle are not being detected on the slaughter or cutting-line because there are no known methods to rapidly, economically and accurately measure them, especially WHC.

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Much effort has been devoted to finding ways of recognizing pork quality in intact carcasses (Chizzolini et al., 1993; Garrido et al., 1994; Kauffman et al., 1993; Oliver et al., 1991; Somers et al., 1985; Warriss et al., 1989, 1991) and methods of identifying aberrant quality have relied primarily on physical or chemical properties. It was believed that pH was one key to understanding postmortem (PM) muscle glycolysis and that it was related to WHC and color (Bendall and Swatland, 1988). More recently it has been generally believed that pH is not totally effective in assessing quality of pre-rigor musculature (Chizzolini et al., 1993; Garrido et al., 1994; Joo et al., 1995; Kauffman et al., 1993). Unfortunately, there is no invasive method for measuring WHC, although Kim et al. (1995) investigated a tensiometer that requires modification if it is to be applied to the slaughter-line. After the physical basis of electrical conductivity in PM muscle was described in detail in a working hypothesis by Swatland (1980a, b), the electrical properties to detect pork quality have been studied (Kleibel et al., 1983; Schmitten et al., 1987; Seidler et al., 1987; Warriss et al., 1991). With modern instrumentation, the measurement of optical or electrical properties of meat may contribute to more reliable measurements to complement pH. Some researchers have reported that electrical conductivity can be used to predict PSE and can replace traditional pH measurements (Chizzolini et al., 1993; Oliver et al., 1991; Kleibel et al., 1983; Pfutzer et al., 1981; Schmitten et al., 1987; Schwagele, 1991). However, they have not demonstrated this to predict the other pork quality classes of RFN, DFD and RSE.

In the previous study on the comparison of various techniques to predict ultimate quality and marbling (Joo et al., 1999), four instruments including MQM, HGP, SRP and NpH, were selected as the most promising probes. In the present study, we have tested their effectiveness for categorizing pork into the categories and predicting various levels of intramuscular fat under commercial condition.

MATERIALS AND METHODS

After completing previous experiment (Joo et al., 1999) and determining the most appropriate methods to further consider (primarily based on accuracy because all methods selected were rapid and invasive), 302 pork carcasses were selected in three sessions during one week. The carcasses were sampled randomly at 24 hr PM just prior to fabrication. Each pre-selected carcass was removed from the cutting line and probed at various anatomically prescribed sites along the longissimus thoracis et lumborum (LTL) by MQM, HGP, SRP, and NpH as described in former paper (Joo et al., 1999). Backfat thickness at the last costa and carcass weight were measured before probing to help describe the population used for this study.

Each technician was responsible for a maximum of two instrument measurements, thus it required less than 10 min to record all measurements. For each of the 302 carcasses, efforts were made to maintain consistency in measuring at the same anatomical location and to follow the same procedure for each probe. Also the same person using the same instruments in previous experiment was assigned to make similar measurements for each carcass. Five carcasses were railed out at a time until approximately 100 had been measured each day. After probing, the loin of the carcass was removed to determine ultimate quality. The measurements included filter paper wetness (FPW), Minolta Chromameter (MC) L* value, pH by Omega pH meter (OpH) and subjective scores (SC, SF and SM) as described in former experiment. Percent drip loss (PDL) was calculated using FPW values as described by Kauffman et al. (1986).

Similar statistical analysis as used in previous experiment was employed. Additionally, logistic discriminant analysis procedures were used to determine the accuracy of predicting quality groups by individual, and combinations of, independent variables as described by Kauffman et al. (1993).

RESULTS AND DISCUSSION

Means and standard deviations of the quality characteristics studied were calculated based on the WHC (PDL) and color (L*) parameters shown in table 1 and figure 1. Because these carcasses were randomly selected, they represent a normal commercial situation with approximately 7% of the carcasses classified as PSE, 14% RSE, 47% RFN and 33% DFD. These results show a much higher incidence of DFD than has

Table 1. Measurements[A] of pork carcasses for each of the four ultimate quality groups

Measurements[B]	Ultimate quality groups				
	PSE 21 (7%)	RSE 41 (14%)	RFN 141 (47%)	DFD 99 (33%)	Overall 302 (100%)
PDL (%)	7.9[a] ±1.3	7.8[a] ±1.8	3.6[b] ±1.3	2.2[c] ±1.2	4.6 ±2.5
L*	52.1[a] ±1.9	47.0[b] ±2.1	46.2[b] ±2.1	39.6[c] ±2.5	44.5 ±44
OpH	5.47[a] ±0.15	5.58[b] ±0.20	5.64[b] ±0.17	6.02[c] ±0.28	5.75 ±0.29
FPW	134[a] ±22	132[a] ±32	61[b] ±22	38[c] ±19	68 ±41
SC	2.1[a] ±0.8	2.8[b] ±0.6	2.9[b] ±0.4	3.7[c] ±0.5	3.1 ±0.7
SF	1.8[a] ±0.7	2.1[b] ±0.8	2.9[c] ±0.7	3.8[d] ±0.8	3.0 ±1.0
SM	1.6[ab] ±0.6	1.5[a] ±0.6	1.9[bc] ±0.9	2.1[c] ±0.8	1.9 ±0.8
BF	1.3 ±0.2	1.3 ±0.2	1.3 ±0.2	1.3 ±0.2	1.3 ±0.2
CW (kg)	80.1[a] ±5.0	82.8[b] ±7.7	79.7[a] ±6.3	82.4[ab] ±6.8	81 ±6.8

[A] Mean ± standard deviations.

[B] PDL=% drip loss; Oph=omega pHu value; FPW=filter paper wetness; SC=subjective color score (1=pale, 5=dark); SF=subjective firmness/wetness score (1=soft, 5=firm); SM=subjective marbling score (1=devoid, 5=abundant); BF=backfat thickness; CW=carcass weight.

[a,b,c,d] Means in each row among groups having a different superscript are different, $p<0.05$.

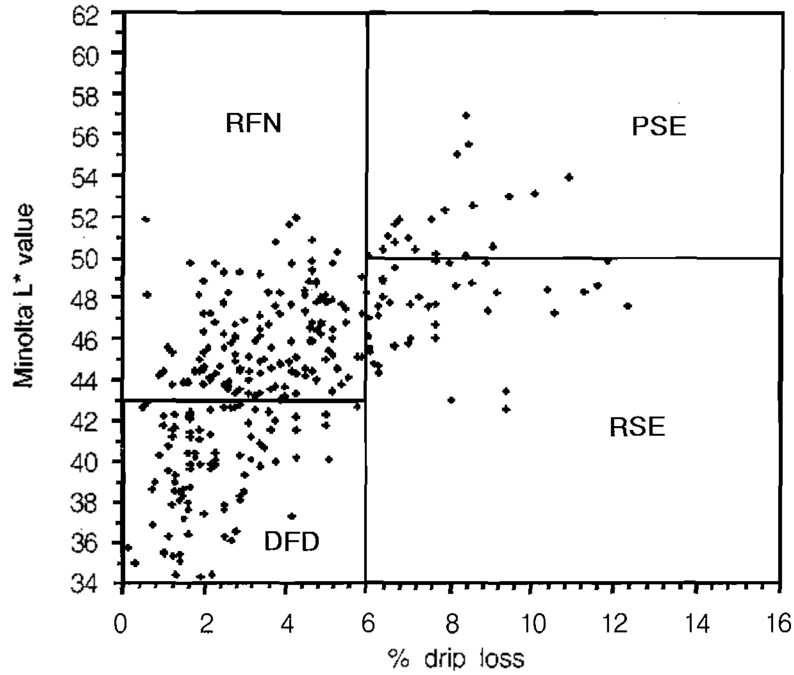

Figure 1. Identification of four pork quality classes (N=302)

been seen in previous studies (Kauffman et al., 1992). The PSE and RSE classes were not significantly ($p<0.05$) different from each other for PDL and FPW (inverse measures of WHC), but they were both significantly higher than RFN which was in turn higher than DFD for PDL and FPW. The RSE and RFN classes were not significantly different from each other for L* and SC (measures of color) and pHu, but they were both significantly different ($p<0.05$) from both PSE and DFD (PSE was significantly lighter/paler and lower in pH; DFD was significantly darker and higher in pH). These results differed from previous experiment (Joo et al., 1999). Only SF was significantly different ($p<0.05$) among all four pork quality groups. The RSE carcasses were found to be leaner (based on SM scores) than RFN, however backfat thickness (BF) was not significantly different. Carcass weight did not show a significant trend across quality groups.

Means and standard deviations for the various measurements were calculated for each of the four quality groups (table 2). The mean values from MQM, HGP and NpH were not significantly ($p>0.05$) different between RSE and RFN. However, the SRP measurements for RSE and RFN were significantly ($p<0.05$) different. From these results, it could be suggested that light reflectance measurements (MQM, HGP) can not identify the difference between RSE and RFN because their color is similar. Although there was no significant difference ($p>0.05$) in SRP between PSE and RSE or RFN and DFD, it could also be suggested that the electrical resistance can classify the

Table 2. Measurements[A] for the four quality groups and their relationship to ultimate quality parameters (N=302)

Measurements[B]	Quality group				r values	
	PSE	RSE	RFN	DFD	PDL[C]	L*
MQM	49^{a} ±4	46^{b} ±2	45^{b} ±2	40^{c} ±3	0.57***	0.80***
HGP	95^{a} ±23	84^{b} ±13	79^{b} ±12	58^{c} ±14	0.54***	0.73***
NpH	5.53^{a} ±0.13	5.65^{b} ±0.14	5.71^{b} ±0.14	6.09^{c} ±0.29	-0.57***	-0.75***
SRP (Ω)	86^{a} ±15	89^{a} ±18	102^{b} ±18	105^{b} ±14	-0.39***	-0.30***

[A] Mean ± standard deviations.
[B] MQM=meat quality marbling; HGP=hennessy grading probe; NpH=NWK pH meter (K21); SRP=sensoptic resistance probe.
[C] PDL=% drip loss.
[a,b,c] Means in each row among groups having different superscripts are different, $p<0.05$.

Table 3. Use of all measurements collectively to categorize four quality groups by discriminant analysis (N=302)

Code[b]	Actual quality groups[a]																TCP[c] (%)
	A				B				C				D				
	(Predicted quality groups)																
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	
N	16	2	3	0	15	12	12	2	30	38	60	13	0	2	29	68	52
S	11	3	4	3	21	3	3	9	24	27	24	66	11	8	22	58	32
M	11	4	6	0	6	21	21	4	8	54	62	17	0	2	11	86	60
H	16	4	0	1	13	11	11	3	18	29	78	16	1	0	6	92	65
NS	13	3	5	0	16	11	11	2	17	27	85	12	0	6	26	67	58
NM	11	4	6	0	7	22	22	3	7	57	63	14	0	1	17	81	59
NH	16	3	1	1	13	13	13	2	16	38	76	11	1	0	19	79	61
SM	11	4	6	0	7	19	19	4	7	38	79	17	0	3	10	86	65
SH	15	4	2	1	12	14	16	3	16	35	76	14	1	2	5	91	65
MH	11	5	4	1	6	23	23	3	9	52	63	17	0	2	7	90	62
NSM	11	4	6	0	6	19	19	3	6	36	85	14	0	2	16	81	65
NMH	11	4	6	0	7	23	23	2	7	52	71	11	0	2	12	85	63
NSH	13	4	3	1	14	14	14	2	14	33	85	12	1	4	16	78	62
SMH	11	4	5	1	6	19	19	3	7	38	80	16	0	2	7	90	66
NSMH	11	4	6	0	6	19	19	3	6	38	86	11	0	3	10	86	67

[a] A=PSE, B=RSE, C=RFN, D=DFD.
[b] N=NWK pH meter (K21), S=sensoptic resistance probe, M=meat quality marbling, H=hennessy grading probe.
[c] Total proportion of correct.

difference between exudative (i.e., PSE and RSE) and non-exudative (i.e., RFN and DFD) groups.

Correlations for the independent measurements with PDL and L* show that MQM, HGP and NpH measurements accounted for about 32% of the variation in PDL and about 60% of the variation in L* values. These results at 24 hr PM are much improved compared with those at 45 min PM investigated by Kauffman et al. (1993) where only about 25% of the variation in L* values and less than 5% for PDL was accounted for. Therefore, if the electrical resistance can classify differences in exudativeness in meat, it might be desirable to use a combination of measurements, i.e. HGP or MQM and SRP.

It was anticipated that combinations of measurements might prove useful. When discriminant analysis was used to sort carcasses into quality groups, the proportions of correct classifications were 52% for NpH, 32% for SRP and 60% for MQM (table 3). The highest proportion was 65% for HGP. When comparing HGP with MQM, 44% of the RFN samples were sorted incorrectly as RSE or PSE by MQM, whereas 33% of the RFN samples were sorted incorrectly by HGP. Also, MQM sorted 13% of the DFD samples incorrectly whereas HGP only sorted 7% of the DFD samples incorrectly. This result clearly suggests that MQM does not identify exudativeness easily since 38% of the samples were sorted as RSE, although they should have been RFN. This is probably due to use of near-infrared wavelength as discussed earlier (Joo et al., 1999). Both MQM and HGP selected about 30% of samples that were PSE or RSE incorrectly as RFN or DFD, and, they both sorted about 12% of the RFN samples incorrectly as DFD.

When only NpH was used, 48% of the RFN samples were incorrectly sorted as RSE or PSE, 31% of the DFD samples were sorted incorrectly and 28% of the PSE samples were sorted incorrectly. Any combination of NpH and MQM did not improve the proportion of correct predictions, and when only SRP and MQM were combined, 65% were grouped correctly (table 3) which was the same as using HGP alone and little or no improvement was gained by using extra variables.

When all independent variables were included to sort carcasses into correct groups (PSE, RSE, RFN and DFD), the success was only 67% (table 3), which was little better than guessing and only 10% more of an improvement than those of Kauffman et al. (1993). Therefore, it was suggested that a higher proportion of correct predictions might be obtained if the traditional three categories were used, because most of the instruments have confused RSE and RFN groups. Thus, RSE and RFN were merged so that there were only three groups (PSE, RSE+RFN, DFD; i.e. Pale group, Reddish-pink group and Dark group) differentiated

Table 4. Use of all measurements collectively to categorize four quality groups by discriminant analysis (N=302)

Code[b]	Actual marbling groups[a]									TCP[c] (%)
	P			R			D			
	(Predicted marbling groups)									
	P	R	D	P	R	D	P	R	D	
N	17	4	0	67	100	15	1	30	68	61
S	13	5	3	62	34	86	17	23	59	35
M	11	10	0	16	144	22	0	11	88	80
H	17	3	1	37	119	26	1	6	92	75
NS	15	6	0	51	116	15	3	27	69	66
NM	11	10	0	16	147	19	0	15	84	80
NH	18	2	1	37	130	15	1	15	83	76
SM	11	10	0	19	141	22	0	12	87	79
SH	15	5	1	43	118	21	1	6	92	75
MH	11	9	1	16	144	22	1	8	90	81
NSM	11	10	0	16	147	19	0	15	84	80
NMH	11	10	0	17	147	18	0	12	87	81
NSH	16	4	1	44	123	15	1	16	82	73
SMH	11	9	1	19	141	22	1	8	90	80
NSMH	11	10	0	16	149	17	0	11	88	82

[a] P=PSE, R=RSE, D=DFD.

[b] N=NWK pH meter (K21), S=sensoptic resistance probe, M=meat quality marbling, H=hennessy grading probe.

[c] Total proportion of correct.

by color which then can be used for discriminant analysis. Table 4 is included to show that MQM could now correctly sort the same set of data into the new set of three groups with 80% accuracy, which is the best of all measurements. However, MQM still classified almost half of the PSE samples incorrectly. Only about 11% of the reddish-pink group were classified incorrectly as PSE and about 15% as DFD by MQM. The proportions of correct classifications for HGP, NpH and SRP were 75%, 61% and 35%, respectively. HGP classified only 4 out of 17 of the PSE group incorrectly but 30% of the reddish-pink samples were classified incorrectly as PSE by HGP.

One important problem seems to lie with the inconsistent and less than perfect relationship between pHu and ultimate pork quality. Bendall and Swatland (1988) reviewed the relation of DFD to pHu, including use of a threshold value of pHu for criteria of DFD. In this study, it was observed that the measurements of pHu could not be used to categorize quality groups accurately, yet it has been used for a long time by many researchers (Bendall and Swatland, 1988). Almost one-third (30%) of the DFD carcasses were classified as non-DFD and almost half (45%) of reddish-pink group was classified as PSE or DFD by NpH. Furthermore, when it was combined with MQM or HGP, the proportion of correct classifications was not elevated. This imperfect relationship between pHu and pork quality is the reason why pHu has been excluded as a selection criteria for pork quality in previous experiment.

When all independent variables were included to sort carcasses into correct pale, reddish-pink and dark groups, the success was 82%, which was very little improvement on using MQM alone. Is 80% satisfactory enough to be considered for commercial sorting individual pork carcasses into the traditional three quality groups? It seems that this question needs to be left to be answered by the industry.

It was anticipated that if the PSE group was combined with RSE, and RFN combined with DFD, then the proportion of correct classifications would be elevate. Kauffman et al. (1993) showed improved prediction accuracy when they used only these two groups, i.e., acceptable or unacceptable WHC. However, this did not prevail in this study. Table 5 indicates the numbers of carcasses that were predicted to be in acceptable (RFN+DFD) or unacceptable (PSE+RSE) WHC groups when all measurements were used, and the proportion of correct classifications was less than 80%, which was worse than when the data was selected into three groups. The combination of SMH was better than NSMH (table 5). The poor prediction of the light reflectance measurements (HGP, MQM) for predicting only these two categories is probably due to their design which is to measure color, but not

WHC. SRP was better than NpH, and this was expected because the electrical resistance is more sensitive to exudate in meat than NpH. This is in agreement with some reports which have suggested that electrical properties can be used to predict PSE and normal meat and can replace traditional pH muscle measurement (Oliver et al., 1991; Schmitten et al., 1987; Schwagele, 1991; Swatland, 1980a, b). Because of the poor prediction results above and because the primary purpose of almost any instrument is predicting PSE pork in the slaughterhouse, the division of PSE and non-PSE groups was investigated.

Table 5. Use of all measurements collectively to categorize two quality groups (exudate and non-exudate) by discriminant analysis (N=302)

Code[b]	Actual quality groups[a]				TCP[c] (%)
	Exudate		Non-exudate		
	(Predicted quality groups)				
	Exudate	Non-exudate	Exudate	Non-exudate	
N	51	11	97	143	64
S	38	24	70	170	69
M	44	18	69	171	71
H	47	15	60	180	75
NS	48	14	66	174	74
NM	46	16	71	169	71
NH	51	11	79	161	70
SM	41	21	52	188	76
SH	47	15	60	180	75
MH	47	15	73	167	71
NSM	44	18	51	189	77
NMH	45	17	75	165	70
NSH	48	14	67	173	73
SMH	42	20	55	185	75
NSMH	43	19	55	185	75

[a] Exudate=PSE+RSE, Non-exudate=RFN+DFD.
[b] N=NWK pH meter (K21), S=Sensoptic Resistance Probe, M=Meat quality marbling, H=Hennessy grading probe.
[c] Total proportion of correct.

Table 6 is included to show that when PSE and the other groups (RSE+RFN+DFD) were divided, then the proportion of correct classifications using all measurements combined was elevated to 88%. Using MQM alone gave 87% prediction accuracy and only a 2% improvement was made with addition of other variables. Although as groups are combined there is a necessary increase in probability by chance alone of improving the prediction accuracy as described by Kauffman et al. (1993), the 87% accuracy for predicting PSE pork could be enough to use commercially sorting system on cutting-line. The other measurements (except NpH) also showed much higher prediction accuracy for PSE vs non-PSE than for exudative vs non-exudative.

Table 6. Use of all measurements collectively to categorize two quality groups (PSE and non-PSE) by discriminant analysis (N=302)

Code[b]	Actual quality groups[a]				TCP[c] (%)
	PSE		Non-PSE		
	(Predicted quality groups)				
	PSE	Non-PSE	PSE	Non-PSE	
N	18	3	100	181	66
S	13	8	81	200	71
M	11	10	28	153	87
H	20	1	55	226	81
NS	17	4	76	205	74
NM	11	10	23	258	89
NH	19	2	72	209	75
SM	11	10	25	253	88
SH	19	2	58	223	80
MH	11	10	22	259	89
NSM	11	10	24	257	89
NMH	11	10	24	257	89
NSH	19	2	61	220	79
SMH	11	10	25	256	88
NSMH	11	10	26	255	88

[a] Non-PSE=RSE+RFN+DFD.
[b] N=NWK pH meter (K21), S=Sensoptic Resistance Probe, M=Meat quality marbling, H=Hennessy grading probe.
[c] Total proportion of correct.

Table 7 includes a description of 302 carcasses as they represented the three marbling groups based on SM. The measurements of WHC (PDL and FPW) decreased significantly ($p<0.05$) with increasing marbling, SF increased significantly ($p<0.05$) those values with increased marbling, but, the color measurements (L* and SC) were not significantly different ($p>0.05$). This may suggest that marbling of meat affects the WHC. It is perhaps possible that intramuscular fat (IMF) firms up muscle bundles and the dimension of the extracellular space decreases, such that the water in the muscle tissue can not move easily into the extracellular space. The forces restricting the mobility of water in muscle are poorly understood but are apparently determined by the spatial arrangement of muscle proteins (Irving et al., 1990; Pearson and Young, 1989). Moreover, it is not yet known if the differences in WHC of muscle are due to differences in the muscle structures. In this study, we often observed that DFD samples showed

Table 7. Measurements[A] for each of the three marbling groups (N=302)

	Marbling groups[C]			
	Slight	Modest	Abundant	Overall
Measurements[B] N	224	67	11	302
PDL	4.4[a] ±2.5	3.0[b] ±1.9	2.3[b] ±1.3	4.0 ±2.5
L*	44.9 ±4.4	43.3 ±4.2	45.0 ±3.7	44.5 ±44
OpH	5.70[a] ±0.26	5.88[b] ±0.30	5.92[b] ±0.30	5.75 ±0.29
FPW (mg)	75[a] ±4	51[b] ±31	40 ±21	68 ±41
SC	3.0 ±0.7	3.4 ±0.5	3.4 ±0.5	3.1 ±0.7
SF	2.8[a] ±0.9	3.6[b] ±0.9	3.8[b] ±0.6	3.0 ±1.0
SM	1.5[a] ±0.4	2.9[b] ±0.3	4.1[c] ±0.3	1.9 ±0.8
BF (cm)	3.0 ±0.5	3.3 ±0.5	3.6 ±0.5	3.3 ±0.5
CW (kg)	81[a] ±6.8	81[a] ±6.3	82.8[b] ±5.4	81 ±6.8

[A] Means±standard deviations.
[B] PDL=drip loss; FPW=filter paper wetness; OpH=omega pHu value; SC=subjective color score (1=pale, 5=dark); SF=subjective firmness/wetness score (1=soft, 5=firm); SM=subjective marbling score (1=devoid, 5=abundant); BF=backfat thickness; CW=carcass weight.
[C] Based on subjective marbling score; 1<slight 2, 2<modest 4, 4<abundant 5.
[a,b,c] Mean in each row among groups having a different superscript are different, $p<0.05$.

Table 8. Measurements[A] for the three marbling groups and their relationship to subjective marbling score (N=302)

	Marbling groups[C]			r values
Measurements[B]	Slight	Modest	Abundant	SM[D]
NpH	5.76[a] ± 0.24	5.96[b] ± 0.32	6.00[b] ±0.33	0.41***
SRP	98[a] ±18	105[b] ±16	105[b] ±16	0.15**
MQM	4.6 ± 0.8	5.1 ± 0.9	6.3 ±1.6	0.43***
HGP	62[a] ±30	72[a] ±26	94[b] ±61	0.22***

[A] Means±standard deviations.
[B] NpH=NWK pH meter (K21); SRP=sensoptic resistance probe; MQM=meat quality marbling; HGP=hennessy grading probe.
[C] Based on subjective marbling score; 1 < slight 2, 2 <modest 4, 4 < abundant 5.
[D] SM=subjective marbling score (1=devoid, 5=abundant).
[a,b] Means in each row among groups having a different superscript are different, $p<0.05$.

high marbling whereas PSE samples showed low marbling.

Table 8 shows the means and standard deviations for the various techniques for each of the three marbling groups based on SM. Following each set of means, there are the simple correlations between any given independent measurement and SM the total sample size. The MQM measurements of the three marbling groups were significantly ($p<0.05$) different and NpH measurements showed a higher correlation than HGP. There was no significant ($p>0.05$) difference for SRP and also extremely low correlation between the measurements of SRP and SM. Consequently, it was anticipated that MQM and NpH could give a reliable prediction of marbling. This expectation was met when discriminant analysis was used to sort carcasses into three marbling groups. When each of variables was used singly to categorize the carcasses, the proportions of correct predictions were 63% for MQM, 60% for NpH, 58% for HGP and 41% for SRP (table 9). The proportion of correct classifications was 72% when both MQM and NpH measurements were used to predict marbling groups. No other combination of measurements showed better than MQM and NpH which was still not considered satisfactory enough to be used for commercially sorting individual pork carcasses into three marbling groups. Furthermore, when five marbling groups were used as criteria, there were extremely low proportion (below 30%) of correct predictions (data not shown).

From the results of this investigation, the following conclusions were made:

(1) Measurements at 24 hr PM are more adequate predictors of ultimate pork quality than those at 45 min PM.

Table 9. Use of all measurements collectively to categorize three marbling groups by discriminant analysis (N=302)

Code[b]	Actual marbling groups[a] S (Predicted marbling groups) S			M			A			TCP[c] (%)
	S	M	A	S	M	A	S	M	A	
N	166	25	33	30	13	24	4	4	3	60
S	118	26	80	27	7	33	6	5	0	41
M	159	49	16	28	22	17	2	1	8	63
H	152	33	39	35	15	17	4	0	7	58
NS	162	30	32	33	10	24	3	7	1	57
NM	175	40	9	19	34	14	1	2	8	72
NH	165	37	22	31	14	22	3	2	6	61
SM	158	50	16	29	19	19	1	2	8	61
SH	135	58	31	27	21	19	4	2	5	53
MH	160	44	20	30	17	20	2	2	7	61
NSM	173	42	9	22	31	14	1	2	8	70
NMH	176	38	10	21	32	14	1	3	7	71
NSH	163	39	22	32	14	21	2	4	5	60
SMH	150	61	13	19	39	9	1	5	5	64
NSMH	171	46	7	21	35	11	1	3	7	71

[a] S=slight, M=modest, A=abundant.

[b] N=NWK pH meter (K21), S=sensoptic resistance probe, M=meat quality marbling, H=hennessy grading probe.

[c] Total proportion of correct.

(2) HGP, which uses visual light wavelength, is better for predicting color of pork whereas MQM, which used near-infrared light wavelength, is better for predicting exudate of pork.
(3) Although electrical resistance is not appropriate for predicting one of four ultimate pork quality groups for single carcasses, it was better for sorting PSE pork than pHu.
(4) pHu was not always a reliable predictor for pork quality and its relation to both color and WHC of pork muscle should be more carefully investigated.
(5) Both MQM and HGP were considered accurate enough to classify PSE pork on the cutting-line at 24 hr PM.
(6) Electrical properties of muscle are not adequate predictors of marbling on the cutting-line.
(7) MQM was better for predicting marbling than HGP, possibly because MQM uses near-infrared light wavelength (950 nm).

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