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Rapid Methods to Predict Lean Quality Attributes in Pork

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Summary and Implications

Meat quality has a significant impact on the value of pork. This research was conducted to determine if measures taken within the first 24 hours after harvest could be used to predict final meat quality in the domestic and export market. Measurements of loin pH, electrical impedance, and light reflectance were taken at the last rib 22 hours postmortem on 604 pigs in a commercial meat plant. One loin from each carcass was stored for 21 or 42 days to simulate domestic or export handling and shipping. At the conclusion of the storage time, pork color and loin purge were assessed. Measures taken within a day of slaughter were used to construct prediction equations for ultimate color and purge in domestic and export product. Color (L, a measure of lightness) was determined using a colorimeter and purge was defined as the percentage of boneless loin weight found as free liquid in the vacuum package after storage. Prediction equations explained only 21% and 12% of the variation in percent purge for domestic and export product, respectively, and 29% and 44%, respectively, of the variation in L*. Electrical impedance and light reflectance were of limited value in predicting pork quality within narrow quality classes when the measurements were made on cold carcasses.*

Introduction

Consumers use pork color as a selection criterion when purchasing at retail. Thus, color is of considerable economic value. Similarly, loss of loin weight as liquid within the vacuum package (purge) is of economic consequence to processors and retailers. This is true both in domestic and export markets. Many companies that purchase pork from packing plants impose a minimum color standard and have expectations as to the amount of purge that will occur within the vacuum package. For a packing company involved in the harvest and processing of pork, the ability to sort pork into known quality classes on the basis of ultimate color and purge would be of considerable value.

Many methodologies have been applied to prediction of pork quality. Recently, attention has been directed toward electrical impedance as a possible indicator of pork quality. Unfortunately this technology requires measures be taken on hot, pre-rigor carcasses. A more logical location in the processing plant to make such measures would be after chilling, when the normal flow of product through the facility could be better managed.

In addition, light reflection within the lean (which can be measured from an optical fat probe) has been suggested as an indication of pork color. Thus, the objective of this research was to determine if measures taken within the first 24 hours after harvest could be used to predict final meat quality in the domestic and export market.

Procedures

Two commercial dam lines were crossed with two commercial sire lines and the progeny (barrows and gilts) were harvested at a commercial packing plant during two seasons (summer and winter). There were four harvest dates per season with about 80 animals per day. There were 604 pigs used in the study.

Within 30 minutes postmortem, a Fat-O-Meater™ Optical Probe (SFK Technology, Herlev, Denmark) was used to measure fat and muscle depth on each carcass. Measures were taken at the 10/11 rib interface. Carcass weight was also recorded. About 21 hours later, muscle pH (with a probe electrode), electrical impedance (NTE Meat Quality Scanner, model MQS-1, Barcelona, Spain) and light reflectance (Hennessy Grading System probe, model GP4/MPS7, Auckland, New Zealand) measurements were made at the last rib.

The electrical impedance instrument actually generates six distinct data points, representing the real and imaginary components of impedance at three different wavelengths (5.6, 56, and 112 kHz). A preliminary analysis was conducted to determine which, if any, of these variables ought to be included in the final model. This was necessary because of the high degree of interrelationship between the measures. For purge, the imaginary portions of impedance measured at 56 and 112 kHz were of greatest significance. For color, no relationships were found, although these two variables were also used in color prediction equations to maintain consistency in the analyses.

Table 1. **Means and variation for carcass traits of pork carcasses used as a source for domestic pork loins.**

	Summer harvest			Winter harvest		
	Mean	SD[a]	CV[b]	Mean	SD	CV
Hot carcass weight, kg	197.1	19.5	9.9	187.6	17.9	9.5
Fat depth, mm	18.0	4.1	22.8	18.0	4.1	22.8
Muscle depth, mm	56.1	6.7	11.9	51.7	7.3	14.1
Ultimate L*	50.2	2.8	5.6	46.8	4.1	8.8
Ultimate purge, %	3.1	1.3	41.9	4.1	1.9	46.3

[a]SD = standard deviation.
[b]CV = coefficient of variation; SD/mean x 100.

Table 2. **Means and variation for carcass traits of pork carcasses used as a source for export pork loins.**

	Summer harvest			Winter harvest		
	Mean	SD[a]	CV[b]	Mean	SD	CV
Hot carcass weight, kg	196.6	20.7	10.5	187.2	17.5	9.3
Fat depth, mm	17.7	4.1	23.2	17.7	3.6	20.3
Muscle depth, mm	55.8	6.9	12.4	52.2	6.7	12.8
Ultimate L*	49.0	2.5	5.1	48.0	2.6	5.4
Ultimate purge, %	3.1	1.4	45.2	3.6	1.4	38.9

[a]SD = standard deviation.
[b]CV = coefficient of variation; SD/mean x 100.

A boneless loin was obtained from each carcass and vacuum packaged. To mimic handling of product in the domestic market, one half of the loins were stored at 1 C for 21 days. For the other half of the loins, handling for the export market was simulated by storage at 1 C for 42 days. All loins were shipped from Nebraska to Missouri during storage.

At the completion of storage time, muscle color (L*) was measured at the anterior end of the loin with a Color-Tec colorimeter (Clinton, NJ). Purge loss percentage was quantified by weighing the boneless loin in the vacuum bag and then without the bag.

It should be noted that the instruments for light reflectance and impedance were designed for measurement on hot carcasses. The equipment in this study was used on cold carcasses because of plant layout and the opportunity to sort prior to fabrication. All other procedures followed manufacturers' recommendations. Regression equations were constructed to explore the relationship between quality (L* and purge) and the objective measures that were taken. For purposes of this analysis, acceptable quality was defined as an L* value less than 50 and purge loss of less than 5%.

Results and Discussion

The populations of carcasses used for this study were fairly consistent for carcass weight and muscle depth (Tables 1 and 2). These traits have coefficients of variation on the order of 10%. Carcass fatness was more variable with a coefficient of variation around 25%. Similarly, ultimate color, L*, had a coefficient of variation between 5 and 9%. The amount of purge, while variable on a percentage basis, was generally low, with means of 3-4%. It is generally difficult for prediction technology to perform well on such a consistent population.

To evaluate the effectiveness of the technology, variables were added to the regression equation in a sequential fashion going from the easiest to the most difficult data to collect. Thus, we began with season, adding carcass weight and characteristics that would normally be collected with the Fat-O-Meater (fat and muscle depth). Color and color variation from the Hennessy Grading Probe were added next, followed by muscle pH. Electrical impedance data were the last group to be added to the model. In this way, it was possible to evaluate the additional increase in predictive accuracy provided by each of the technologies and thus to determine which equation would be most cost effective. Some terms were included in the statistical model despite lacking a significant contribution to the equation. This was to maintain clarity and consistency during evaluation and presentation of the methodologies described here. No differences in interpretation occurred when non-significant terms were removed from the model.

Results for color of domestic (Table 3) and export (Table 4) loins revealed that none of the equations were particularly effective in predicting ultimate L*. In both populations, there was a significant improvement in prediction when color data from the Hennessy Grading Probe were added to the model. Still, only 22 to 38% of the variation in color was explained. The slight improvement in predictive accuracy provided by pH and electrical impedance do not seem to justify the additional expense of data collection in a plant setting.

To evaluate the effectiveness of the prediction equations in allowing a plant to sort pork carcasses at 24 hours on the basis of predicted color in the domestic or

(Continued on next page)

Table 3. Prediction of ultimate color (L*) in pork loins (n=302) destined for the domestic market.

Model[a]	R-square	RMSE[b]	Overall accept, %	Correct accept, %	Incorrect accept, %	Overall reject, %	Correct reject, %	Incorrect reject, %
S	0.00	3.44	0.00	0.00	0.00	100.00	16.22	83.77
S + Carc	0.03	3.40	0.00	0.00	0.00	100.00	16.22	83.77
S + Carc + HGP	0.22	3.07	25.16	23.84	1.32	74.83	14.90	59.93
S + Carc + HGP + pH	0.28	2.95	27.81	26.49	1.32	72.18	14.90	57.28
S + Carc + HGP + pH + EI	0.29	2.95	27.81	26.82	0.99	72.66	15.23	56.95

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as an L* value less than 50.
[b]RMSE = root mean square error.

Table 4. Prediction of ultimate color (L*) in pork loins (n=302) destined for the export market.

Model[a]	R-square	RMSE[b]	Overall accept, %	Correct accept, %	Incorrect accept, %	Overall reject, %	Correct reject, %	Incorrect reject, %
S	0.14	2.32	52.31	50.33	1.98	47.68	10.26	37.41
S + Carc	0.17	2.29	52.31	45.69	1.98	47.68	10.26	42.05
S + Carc + HGP	0.38	1.99	50.00	47.68	2.31	50.00	9.93	40.06
S + Carc + HGP + pH	0.43	1.91	51.98	49.66	2.31	48.01	9.93	38.07
S + Carc + HGP + pH + EI	0.44	1.90	51.98	50.66	1.32	48.01	10.92	37.08

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as an L* value less than 50.
[b]RMSE = root mean square error.

export market, the percentage of loins that would be predicted to be acceptable was determined. The percentages of correct and incorrect decisions were also identified (Tables 3 and 4). To make this calculation, it was presumed that the acceptable risk of an individual loin not meeting the acceptability criterion of L* < 50 was 20% (alpha = 0.2). This level of performance was not well met by any of the equations. For example, in Table 3, the equation containing season, carcass data, and information from the Hennessy Grading Probe correctly predicted that 23.84% of the pork loins for domestic consumption would meet the standard. While only 1.32% of the population was incorrectly accepted, 59.93% of the population was incorrectly rejected. This means that nearly 85% of the loins would have actually met the standard, but the prediction equation would have allowed less than 25% of the population to be accepted. The high level of uncertainty on the quality prediction leads to this conservative result.

One might be tempted to accept a higher proportion of the population based on these data. However, the consequences of a single loin not meeting the color standard are significant. For a meat plant to guarantee every loin will be of acceptable color, the presence of one in five with unacceptable color (the 20% standard set by alpha = 0.2) would be considered a very high failure rate. From this one can conclude that the prediction of ultimate color by the technologies used in this study, and applied the way we applied them, was of limited value.

In a similar way, prediction of ultimate purge percentage was equally unsuccessful (Tables 5 and 6). Here, about 81% of the domestic loins and 87% of the export loins possessed an acceptable level of purge (< 5.0%) yet the most complex equation accepted 18 - 33% of the loins and incorrectly rejected 55-61% of the population. Clearly, prediction of ultimate

Table 5. Prediction of ultimate purge loss in pork loins (n=302) destined for the domestic market.

Model[a]	R-square	RMSE[b]	Overall accept, %	Correct accept, %	Incorrect accept, %	Overall reject, %	Correct reject, %	Incorrect reject, %
S	0.08	0.016	0.00	0.00	0.00	100.00	19.53	80.46
S + Carc	0.09	0.016	2.31	2.31	0.00	97.70	19.53	78.14
S + Carc + HGP	0.18	0.016	15.23	12.91	2.31	84.76	17.21	67.54
S + Carc + HGP + pH	0.18	0.016	20.19	19.20	0.99	79.80	18.54	61.25
S + Carc + HGP + pH + EI	0.21	0.015	20.19	18.87	1.32	79.80	17.88	61.58

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as less than 5% purge loss.
[b]RMSE = root mean square error.

Table 6. Prediction of ultimate purge loss in pork loins (n=302) destined for the export market.

Model[a]	R-square	RMSE[b]	Overall accept, %	Correct accept, %	Incorrect accept, %	Overall reject, %	Correct reject, %	Incorrect reject, %
S	0.03	0.014	52.31	46.31	6.00	47.68	6.28	41.40
S + Carc	0.05	0.014	33.11	29.13	3.97	66.88	8.27	58.60
S + Carc + HGP	0.07	0.014	36.75	32.11	4.63	63.24	7.61	55.62
S + Carc + HGP + pH	0.09	0.014	39.73	34.76	4.96	60.26	7.28	52.98
S + Carc + HGP + pH + EI	0.12	0.014	37.08	32.78	4.30	62.91	7.94	54.96

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as less than 5% purge loss.
[b]RMSE = root mean square error.

purge percentage was not accomplished.

There are several reasons for these results. A significant issue may have been the relatively uniform population of pork carcasses that was studied. They were very similar in weight and did not differ much in ultimate color. Purge, while variable when expressed on a percentage basis, was also fairly consistent with a standard deviation of less than 2%. Had we used a more variable population similar to that found in many pork packing plants, it's possible better results would have been obtained in screening out the unacceptable loins.

Secondly, the technology was applied after approximately one day of chilling. The electrical impedance probe was designed for use on hot carcasses. Space constraints in the plant forced us into using the probe on chilled carcasses. Better results may have been obtained from hot carcasses.

Finally, the ultimate color was defined as coming from the cross-cut surface of the anterior end of the boneless loin. That's because the shoulder end tends to exhibit the worst color from one end of the loin to the other, possibly due to the additional muscles overlapping the end of the loin. Results presented here relate predictive measures taken from the last rib region of the carcass to color of the anterior end of the boneless pork loin.

Conclusion

Results indicate that electrical impedance and light reflectance were of limited value in predicting pork quality (color and purge) within narrow quality classes when the measurements were made on cold carcasses, as in this study.

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