Title: Effects of Genotype and Pre-Slaughter Handling on Pork Quality
NPB #98-166

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I. Abstract: Pork carcasses were electrically stimulated at various times postmortem to investigate how muscle of various genotypes responds to varying stresses. Three modern genotypes were secured from independent suppliers and pigs were fed ad libitum until reaching approximately 110 kg. Pigs were then slaughtered and subjected to a 2 X 2 factorial experiment consisting of two levels of voltages (100 and 200 voltages, 13 pulses) and two times (15 and 25 min postmortem) for electrical stimulation. Muscle samples were taken from a subset of pigs and were subjected to glycolytic potential assays. Electrical stimulation altered ($P < 0.0001$) pH decline and meat quality characteristics. Moreover, time of stimulation and voltage decreased ($P < 0.05$) pH values. Most importantly, genotypes responded differently ($P < 0.05$) to the electrical stimulation insult. In addition, electrical stimulation hastened ($P < 0.05$) the metabolism of glycogen in the muscle and mostly likely was responsible for the adverse pork quality characteristics caused by electrical stimulation. These data show that different genotypes respond differently to stress early postmortem and suggest that genotypes, relatively equal in muscle growth ability, contain inherently different capacities to develop quality pork. More work, however, is needed to pinpoint exactly what is causing these differences across highly selected genotypes and further validate the use of electrical stimulation for studying PSE development.

II. Introduction: Until genetic companies gained a larger share of the market place, selection for superior breeding stock resided in the hands of literally thousands of small independent breeders. As the number of viable breeders decreased, the selection criteria for most modern day swine breeders was based on growth rate and carcass merit, ie. increased muscling. As gains in carcass muscularity and cutability have plateaued, the industry has found itself with a myriad of genetics that yield heavy muscled pigs. Curiously, the resulting meat quality across these genetic lines is not the same. In fact, some heavy muscled pigs produce high quality meat. This contradicts the long held idea that the carcass muscularity and meat quality are antagonistic characteristics. Unfortunately, little data exists regarding how different genotypes respond to a given stress. Therefore, the objective of this study was to determine whether

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different genotypes respond differently to an early postmortem stimulation with electricity.

III. Objectives: Determine the effects of electrical stimulation, and genotype on pork quality traits in halothane-negative pigs.

IV. Procedures:

Animals. One hundred and fifty pigs from three genetic lines were slaughtered. The first line was terminal cross (Lean European terminal sire line) sires mated to Landrace (Duroc-Large White) females. The second line was Duroc-Large White sires mated to Yorkshire-Landrace females. The third line were US Duroc sires mated to Yorkshire by Duroc-Landrace dams.

Slaughter Procedures and Data Collection. Animals were immobilized by electrical stunning and exsanguinated according to normal slaughter procedures. Immediately following exsanguination, temperature and pH measurements were taken from the loin at the last rib. A subset of muscle samples were also taken from the loin for analysis of glycolytic potential. Carcasses were scalded and dehaired. Temperature and pH measurements were taken at the last rib from the left side of the carcass at 10 min. Animals were eviscerated at approximately 12 min. Animals then received one of four treatments (electrical stimulation for thirteen pulses at 100 or 200 volts at 15 or 25 min postmortem). Temperature and pH readings were then taken at 20, 30, 40, 50, and 60 min postmortem.

Carcass Measurements. At 24 hours postmortem, tissue samples were taken from the tenth rib and used to measure drip loss. NPPC color, firmness, and marbling scores along with Hunter (L*a*b*) measurements were also collected from these tissue samples.

Muscle metabolic analysis. Muscle samples were powdered and analyzed for glycolytic potential by summation of glucose, glycogen, glucose-6-phosphate, and lactate levels.

Statistical analysis. All data was subjected to analysis of variance using the General Linear Models and Orthogonal Contrast procedures of SAS (SAS, 1986). All data was subjected to regression analysis to determine the correlation of various measured parameters to meat quality characteristics.

V. Results and Discussion: Table 1 shows that the three genotypes differed only slightly in carcass composition and performance. Animals used in this study had numerically larger loin eye areas but a significant difference was not discovered. Because of the complex nature of the study, treatments and genotypes were compared by means of orthogonal contrast. The contrast between treatments and controls compared the combined means of all treated carcasses against controls. There were significant differences ($P < 0.05$) in the muscle pH of these two groups at 20, 30, 40, 50, and 60 min postmortem (Table 2). The quality measurements of these groups were also significantly different ($P < 0.05$). These differences were expected and validate the usefulness of the electrical stimulation model. Differences in muscle pH at 20, 30, 40, 50, and 60 min were observed between carcasses stimulated at 15 min and those stimulated at 25 min. This finding shows that during the conversion of muscle to meat, time of insult (electrical stimulation) is important. Voltage also affected ($P < 0.05$) pH decline. Animals stimulated with greater voltages tended to have lower pH values. The animals stimulated with 200v had considerably lower quality than those stimulated with 100v (Table 2). There were significant differences (P < 0.05) in muscle temperature at 10, 20, 30, 40, 50, and 60 min postmortem between these groups. This pH/temperature phenomenon is similar to that known to cause PSE pork. There were several differences between genotypes. pH at 20, 30, 40 min postmortem were lower in genotype 1 than for genotypes 2&3 combined (C1, Table 3). This represents a genotype*voltage level interaction. Another interaction of the same type is the significant difference (P < 0.05) of temperature measurements taken at 40, 50, and 60 min postmortem between genotype 2 and genotype 3 (C2, Table 3). Finally, there was a three way interaction between time*voltage level*genotype of temperatures taken at 20, 30, 40 and 50 min postmortem between genotype 1 and genotypes 2&3 combined (D1, Table 3). The reason for this three-way interaction is obvious at this time. The differences in pH and temperature declines of these three lines of superior muscled animals indicate that animals metabolize energy and dissipate heat differently. Muscle glycogen levels of stimulated animals were higher at one min postmortem and lower at 45 min postmortem, which supports this idea. However, glucose, glucose-6-phosphate, and lactate levels were not different at one min but were higher (P < 0.05) at 45 minutes for treated animals (Table 4). Because differences in pH and temperature declines of these three lines of superior muscled animals were detected, we conclude some lines of heavy muscled animals have inherent muscle differences that makes them more susceptible to adverse meat development while others are relatively less sensitive to aggressive handling procedures. Therefore, seedstock suppliers must consider the quality characteristics of a genotype together with rate of gain, feed efficiency and cutability in their selection programs. These data show that genotype affects how muscle tissue responds to handling postmortem and suggests that muscle energy metabolism may be involved. Further research in this area could prove useful and possibly change the way producers select porcine genetics.

Table 1. Mean performance data from the three genotypes used in this study.

Genotype	Average Start Weight	Average Slaughter Wt.	Average Slaughter Age	Average Daily Gain	Average Loin Eye Area
1	28.68	112.59	169	.73	6.838±.908
2	24.07	114.27	179.2	.75	6.899±1.37
3	20.77	115.55	166.3	.83	7.226±.788

All weights measured in kilograms.
LEA measured in square inches.
Age listed in days.

Table 2. Orthogonal Contrasts (P-values)

Orthogonal	Geno-type1	Geno-type2	Treatment vs. Control (A)	Time (B)	Voltage Level (C)	Time* Level (D)	A1	A2	B1	B2	C1	C2	D1	D2
pH 0	.7424	.5802	.8642	.2751	.8206	.1913	.9146	.1522	.3736	.8574	.2775	.9364	.5441	.6898
pH 10	.8892	**.0368**	.1785	.1483	.9701	.8670	.5659	.0617	.6793	.5550	.2222	.6031	.8965	.1203
pH 20	.0882	.1863	**.0059**	**.0338**	**.0062**	.7717	.5915	.1053	.4914	.8508	**.0368**	.5880	.3515	.2943
pH 30	.2374	.2153	**.0001**	**.0191**	**.0001**	.8420	.4438	.0888	.0931	.7480	**.0363**	.7955	.5551	.1694
pH 40	.3171	.0993	**.0001**	**.0038**	**.0001**	.3522	.2900	.4496	.2341	.9068	**.0473**	.6321	.2973	.4010
pH 50	.4054	.1229	**.0001**	**.0012**	**.0001**	.1061	.3363	.5904	.5428	.9663	.2044	.8327	.5187	.3643
pH 60	.5324	.8186	**.0001**	**.0002**	**.0001**	.2878	.1809	.6194	.4589	.6232	.1783	.8308	.4010	.2585
Temp 0	.2890	.3071	.7142	.5477	.0785	.8596	.6324	.8318	.2701	.8629	.1096	.6046	.1686	.8291
Temp 10	.0701	.7417	.1364	.3877	**.0427**	.5737	.2378	.4969	.2375	.8901	.5172	.8901	.4247	.8178
Temp 20	.3862	.1674	.8772	.2143	**.0209**	.9275	.4284	.7449	.2227	.8327	.9298	.6557	**.0415**	.8327
Temp 30	.6880	.8638	.8941	.2391	**.0167**	.7472	.9544	.4129	.2821	.4433	.9910	.0822	**.0044**	.2687
Temp 40	.9972	.9445	.8065	.9907	**.0222**	.7409	.8224	.3219	.5303	.5337	.9589	**.0532**	**.0259**	.3313
Temp 50	.8284	.7588	.7350	.8695	**.0310**	.6053	.6961	.1386	.9847	.3669	.8981	**.0376**	**.0428**	.3669
Temp 60	.6201	.7326	.7796	.9025	**.0227**	.6533	.5921	**.0481**	.8166	.3197	.8771	**.0409**	.1061	.3529
L*	.1588	.9943	.1169	.6007	**.0062**	.7675	.6532	.0609	.3493	.2774	.6905	.4183	.5863	.1498
A*	.3360	.6949	**.0400**	.5859	.2903	.6950	.7625	.2037	.4895	.9251	.6416	.0734	.4715	.4070
B*	.8471	.2447	.3472	.7983	**.0148**	.2755	.8423	.7872	.1391	.3589	.7359	.4788	**.0587**	.9651
Color	.7632	.8107	**.0001**	.1212	**.0001**	.1959	.3240	**.0497**	.9154	.0834	.3766	.3493	.5014	.6879
Firmness	.4465	.4565	**.0001**	.2124	**.0001**	.0953	.1944	.2220	.4618	.4053	.3554	.7210	.4618	.7210
Marbling	**.0080**	**.0001**	.0898	.6195	.4083	.6195	.5061	.0725	1.000	.6863	.8142	.4196	1.000	.6863
Drip Loss	.2017	.1747	**.0042**	.2438	**.0016**	.3466	.1001	.7391	.9617	.3959	.2849	.4340	.2076	.7741
pHu	.3532	.1827	.9813	.1461	.3670	.7091	.9184	.2773	.3202	.2958	.4471	.2428	.4157	.2078

Genotype1 Genotype 1 contrasted to the combined means of genotypes 2&3 across all treatments (controls included).
Genotype2 Genotype 2 contrasted to the means of genotype 3 across all treatments (controls included).
A. All treatments contrasted to controls across all genotypes.
B. Stimulated (15 min) animals contrasted to stimulated (25) min across all genotypes.
C. Animals stimulated at 100v contrasted to those stimulated at 200v across all genotypes.
D. Each treatment (voltage x time) contrasted to the other treatments across all genotypes.
A1. Genotype 1 contrasted to genotypes 2&3 with respect to A.
A2. Genotype 2 contrasted to genotype 3 with respect to A.
B1. Genotype 1 contrasted to genotypes 2&3 with respect to B.
B2. Genotype 2 contrasted to genotype 3 with respect to B.
C1. Genotype 1 contrasted to genotypes 2&3 with respect to C.
C2. Genotype 2 contrasted to genotype 3 with respect to C.
D1. Genotype 1 contrasted to genotypes 2&3 with respect to D.
D2. Genotype 2 contrasted to genotype 3 with respect to D.

Table 3. Means of temperature and pH declines, and meat quality characteristics of stimulated (ES) and control carcasses from three different genotypes.

Genotype	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**
Treatment	Control	15X100	25X100	15X200	25X200	Control	15X100	25X100	15X200	25X200	Control	15X100	25X100	15X200	25X200
pH 0	6.703	6.723	6.719	6.731	6.639	6.740	6.686	6.689	6.707	6.694	6.688	6.711	6.725	6.748	6.706
pH 10	6.580	6.562	6.523	6.531	6.476	6.572	6.513	6.427	6.506	6.505	6.530	6.544	6.580	6.596	6.540
pH 20	6.438	6.420	6.412	6.285	6.336	6.468	6.381	6.408	6.328	6.389	6.429	6.384	6.467	6.403	6.425
pH 30	6.357	6.315	6.295	6.141	6.161	6.374	6.255	6.288	6.153	6.244	6.327	6.253	6.368	6.230	6.270
pH 40	6.269	6.212	6.190	5.993	6.063	6.246	6.150	6.196	6.023	6.116	6.249	6.159	6.250	6.094	6.153
pH 50	6.180	6.105	6.103	5.876	5.972	6.154	6.066	6.095	5.899	6.016	6.164	6.089	6.159	5.955	6.027
pH 60	6.107	6.004	6.015	5.757	5.854	6.076	5.980	6.017	5.800	5.908	6.060	5.957	6.070	5.820	5.898
Temp 0	39.72	39.70	39.59	39.88	40.17	39.64	39.7	39.64	39.75	39.59	39.79	39.73	39.68	39.95	39.70
Temp 10	39.89	40.12	40.04	40.23	40.45	39.99	39.99	39.83	40.09	39.98	39.89	40.03	39.89	40.21	40.02
Temp 20	40.31	40.23	40.01	40.16	40.46	40.14	40.18	40.16	40.48	40.18	40.07	40.03	39.92	40.38	40.08
Temp 30	40.42	40.45	40.12	40.32	40.71	40.47	40.30	40.38	40.68	40.05	40.28	40.16	40.16	40.69	40.50
Temp 40	40.36	40.27	40.07	40.21	40.60	40.42	40.17	40.37	40.49	40.04	40.20	40.03	40.14	40.60	40.56
Temp 50	40.08	39.99	39.71	39.95	40.20	40.18	39.86	40.06	40.17	39.68	39.85	39.70	39.90	40.34	40.35
Temp 60	39.66	39.60	39.32	39.63	39.80	39.83	39.50	39.69	39.82	39.34	39.34	39.36	39.57	40.02	40.12
L*	63.10	63.08	64.57	64.76	65.16	63.92	62.23	62.34	65.17	63.55	61.80	63.50	63.16	63.60	65.17
A*	11.88	12.41	12.38	13.22	12.46	11.85	12.64	12.30	13.11	13.36	12.69	12.85	13.10	12.70	12.48
B*	11.48	11.46	10.16	11.27	11.72	11.35	10.59	11.20	10.95	11.47	11.51	10.97	11.08	11.76	11.73
Color	2.50	2.09	2.05	1.65	1.95	2.20	2.35	2.20	1.75	1.80	2.55	2.00	2.25	1.65	1.95
Firmness	2.56	1.91	2.05	1.35	1.60	2.25	2.15	1.90	1.55	1.75	2.55	2.00	2.00	1.55	1.85
Marbling	1.06	1.00	1.00	1.00	1.05	1.00	1.00	1.00	1.00	1.00	1.50	1.20	1.20	1.25	1.35
Drip Loss	4.56	6.59	5.91	6.88	6.74	6.39	6.05	6.74	7.75	7.01	5.66	5.76	5.53	7.87	6.66
pHu	5.58	5.57	5.59	5.55	5.60	5.59	5.54	5.56	5.57	5.61	5.54	5.55	5.57	5.58	5.54

Table 4. Muscle glycolytic potentials of stimulated (ES) and control carcasses.

Treatment	Glycogen (µmole/g tissue) 1 min	Glycogen (µmole/g tissue) 45 min	Glucose (µmole/g tissue) 1 min	Glucose (µmole/g tissue) 45 min	Glucose-6-phosphate (µmole/g tissue) 1 min	Glucose-6-phosphate (µmole/g tissue) 45 min	Lactate (µmole/g tissue) 1 min	Lactate (µmole/g tissue) 45 min
Control	61.7 ± 5.6^{ab}	61.5 ± 6.5^{ab}	0.85 ± 0.11^{a}	1.43 ± 0.08^{b}	6.73 ± 0.70^{b}	3.90 ± 0.51^{a}	47.2 ± 1.7^{a}	59.3 ± 2.2^{b}
ES	70.8 ± 8.4^{b}	53.0 ± 6.5^{a}	0.78 ± 0.10^{a}	2.50 ± 0.12^{c}	7.20 ± 0.70^{b}	5.57 ± 0.44^{b}	47.2 ± 2.1^{a}	84.7 ± 3.3^{c}