DETERMINATION OF AN OPTIMAL LOW LEVEL ELECTRICAL STIMULATION TREATMENT REQUIRED TO MAXIMIZE SELECTED QUALITY AND YIELD FACTORS IN A BONELESS PRERIGOR CURED, SECTIONED AND FORMED HAM ROAST

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SUMMARY: When considering all parameters it would appear that the 180 volt ES prerigor treatment would produce an acceptable quality ham roast and also result in the economic gains of hot boning.

INTRODUCTION: Implementation of electrical stimulation (ES) in the meat processing industry has gained popularity in beef and lamb slaughter as a way to reduce processing times and improve tenderness (Cross, 1979; Dutson, 1981). Research and utilization of ES in pork processing has been limited (Ockerman and Kwiatek, 1984; Dutson and Pearson, 1985). The few reported ES studies in pork have produced either detrimental effects or no effects at all in porcine muscle. Lawlis (1985) used a variety of voltage treatments (0-90-180-540 volts) for manufacture of cured, tumbled, boneless ham roasts and except for the 540 volt treatment, he demonstrated that the other low voltage level ES treatments in combination with hot processing produced no detrimental effects and gives the possibility of reduced costs. Therefore, the objective of this investigation was to determine an optimal low level electrical stimulation treatment on prerigor porcine muscle that maximizes quality and yield in a boneless cured, sectioned and formed ham roast when compared to a postrigor control.

MATERIALS AND METHODS: Twenty-five heavy gilts (Range=134.5-157.3 kg) were obtained to provide fifty sides used in this investigation. The experimental design can be found in Table 1.

Table 1: Experimental Design

(25 hogs = 50 sides total)

Rigor condition at time of cure	Prerigor				(Control) Postrigor
ES Voltage Level[a]	0	90	180	270	0
Number of Hams	10	10	10	10	10
Number of Roasts	30	30	30	30	30

Note: Three roasts were made from each whole ham, resulting in 30 observations per treatment.

[a]Electrical Stimulation was applied 40-45 minutes post-exsanguination, 1.5 seconds on/1.5 seconds off for 20 impulses

Each side was randomly assigned a rigor-ES treatment group (pre- and postrigor with 0-90-180-270 volts). Application of low voltage electrical stimulation was conducted 40-45 minutes postmortem, immediately following splitting of the carcass. The electrode was placed in the shoulder region of the carcass using a Jaesac Stimulator at an impulse rate of 1.5 seconds on/1.5 seconds off for a total of 20 impulses.

Immediately after the ES treatments, the sides were removed from the slaughter rail to facilitate ham removal. Each ham was boned and separated into the three major muscle regions, (1) semimembranosus, (2) biceps femoris/semitendinosus, and (3) quadriceps. All visible external and intermuscular fat was removed. The procedure for the conventional postrigor control group was the same as the prerigor-ES treatment groups except the procedures were conducted at 24 hours postmortem.

The three muscle regions of the ham were weighed together, then subjected to multiple stitch needle injection with a Fomaco pickle injector (Model FMG 20S) calibrated to deliver a 120% pump of green weight. The curing brine was composed of 84.7% water, 10% salt, 2.5% sucrose, 2.5% tripolyphosphate, 0.25% sodium erythorbate, and 0.075% sodium nitrite.

Immediately after injection, each muscle was sliced into uniform slices (2.5 cm) on a Hobart (Model 1612) slicing machine. Additional brine was added to account for any loss of brine during the slicing process. All muscle slices were put into a container and thoroughly mixed manually. The muscle sections were divided into three equal lots.

The muscle sections of each lot was placed into a plastic bag and manually stuffed into a 9.5cm. Viskase pre-smoked, 6M casing (Viskase Corp., Chicago, IL). Three boneless ham roasts (approximately 0.91-1.82 kg/roast) were made from each whole ham. Any residual brine left in the mixing container was divided equally among the three plastic bags/roasts. Pre-cook weights were recorded. The stuffed products were placed into an Alkar smokehouse with automatic time, temperature and relative humidity sequence controls and cooked to an internal temperature of 68.3°C using the cooking schedule in Table 2. Roast weights were recorded 24 hours post cooking. From this point, tests were conducted for objective and subjective measurements.

Table 2: Cooking Schedule using the Alkar Smokehouse

Cooking Cycle	Dampers	Temperature (°C) Dry Bulb	Wet Bulb	Time	Smoke
1	Auto	39	54	45 min.	Auto
2	Closed	43	66	2 Hours	On
3	Closed	68	85	2 Hours	On
4	Auto	74	88	*	Off
5	---	---	---	Shower 15 minutes	---

* Cooked at this cycle until an internal temperature of 68.3°C was reached.

Sampling Procedures

Random samples for pH, salt soluble proteins (SSP), and water binding potential (WBP) determinations were taken from the ham roasts immediately prior to stuffing, from meat pieces of each roast utilizing a 2.5 cm. coring tool. From these core samples, duplicate measurements were taken for pH, total

moisture, SSP, and WBP.

After cooking, 0.3 cm thick slices were taken from the end of each roast and evaluated objectively and subjectively. A total of sixteen slices were removed from each roast. Ten slices were used for sensory panel evaluation and the remaining were used for testing bind force/strength via the Instron Universal Testing Machine (Instron Corp., Canton, MA).

Core samples for the 36 hour carcass pH determination were removed from the posterior end of the longissimus dorsi muscle of the carcass. The purpose of the 36 hour pH measurement was to compare the carcass pH against the finished product pH.

Objective Tests:

pH Determination

The pH measurements for all samples and treatments were taken before and after electrical stimulation. Additionally, pH measurements were taken immediately post curing and pre- and post-cooking. The pH of the longissimus dorsi muscle were also determined for all sides at 36 hours post-mortem. All samples used for pH determination were taken from the ham roasts except for the 36 hour carcass longissimus dorsi pH measurement.

The pH measurements were obtained using either an immersion electrode attached to a Corning Model 7 pH meter or a puncture electrode attached to a Corning Model 103 portable digital pH meter.

Salt Soluble Protein (SSP) Determination

The salt soluble protein (SSP) concentration was determined by Biuret method in a procedure devised by Johnson and Henrickson (1970) and they defined SSP as including water soluble and salt soluble proteins in a three percent salt solution.

Water Binding Potential (WBP) Determination

The centrifuge method developed by Miller et al. (1968) was used to determine water binding potential in this experimental study. The water binding potential is reported as a percentage of bound water.

Total moisture, required to calculate water binding potential, was determined by using the oven dry method (Ockerman, 1985).

Cohesiveness/Bind Force Determination

The degree of cohesion between muscle pieces was determined on 0.3 cm thick X 2.5 cm wide slices from the cooked ham roasts using the Instron Universal Testing Machine (Model 1132). The slices were placed into gripping jaws (Ockerman et al., 1988) across the width of the slice and force was applied perpendicular to the junction site. The bind force/strength measurement was recorded as the peak force (grams) to separate the muscle-muscle bond.

Cooked Yield

The cooked yield was calculated by dividing the 24 hour cooked chilled weight by the pre-cook stuffed weight times 100.

Subjective Tests:

Histological Evaluation

A slice of semimembranosus excised approximately one hour post-ES were sectioned and haematoxylon-eosin stained.

The stained slides were evaluated for sarcolemma disruption, nuclei clarity and organization, and the amount of contracture banding and tearing. The slides were scored on a three point scale (Cassidy, 1977).

Sensory Evaluation

Sensory evaluation of each roast was conducted using an eight member sensory panel.

Statistical Analysis

The data collected in this study was analyzed using the Statistical Analysis System (SAS; SAS Institute Inc., Cary, NC, 1988). Analysis of variance (ANOVA) was performed by using the General Linear Model (GLM) procedure found in SAS. Least square means (LSM) and standard errors (SE) were calculated for all the dependent variables in the general linear model. Duncan's multiple comparison test was utilized to determine any differences among the treatment means.

RESULTS AND DISCUSSION:

pH Measurements

Table 3 indicates that the pre-ES pH values for the postrigor treatment and the prerigor ES treatments were not statistically different.

The post-ES pH mean values for the prerigor ES and postrigor treatments were significantly different and the prerigor zero volt ES treatment and postrigor control treatment (zero ES) values were higher ($P<0.05$) than the 90, 180, and 270 volt prerigor ES treatment means. Additionally, the pH change for the prerigor zero voltage ES treatment and postrigor treatment-zero voltage were lower ($P<0.05$) than the 90, 180 and 270 ES voltage groups pH change.

The post curing pH means for the postrigor control were lower ($P<0.05$) than the other pH mean values for the prerigor ES treatments. This is due to the prerigor tissue having less time for glycolysis to proceed, thereby having a higher muscle pH when compared to the normal pH of postrigor muscle tissue.

The postrigor control pre-cook pH mean was identical to the 180 and 270 volt prerigor ES treatments but these values were lower ($P<0.05$) than the zero and 90 volt prerigor ES treatments. The reason the 180 and 270 ES voltage treatments had similar pre-cook pH values to the postrigor control is that the 180 and 270 voltage ES treatments probably accelerated prerigor postmortem glycolysis sufficiently enough to obtain a pH level approximately the same as the postrigor control treatment.

The postrigor treatment had the lowest post-cook pH value (6.12) and was lower ($P<0.05$) than the zero, 90, and 270 volt prerigor ES post-cook pH means but not significantly different from the 180 volt prerigor ES group; however, there was only a 0.09 unit pH range among all the post-cook pH measurements.

The 36 hour carcass pH measurements for the postrigor treatment was not statistically different from the other prerigor ES treatments.

Pre-Cook Salt Soluble Protein (SSP)

The postrigor treatment had the highest total pre-cook SSP (50.14 mg SSP/gm sample) for all treatments in Table 4. Only the zero and 90 volt prerigor ES treatments were significantly lower than the postrigor, zero voltage control. The 180 and 270 prerigor ES treatments and the postrigor control were not different ($P<0.05$). The postrigor control had the largest pre-cook SSP value, which is contradictory to what other researchers have found. A possible explanation for this outcome is that the postrigor control being held in the cooler 24 hours may have had enhanced proteolytic enzyme activity causing more

myofibrillae degradation to occur, resulting in a greater SSP concentration than other prerigor ES treatments. All three ES groups (90, 180, 270 volt) all have SSP values within a range for adequate bind.

Pre-Cook Water Binding Potential (WBP)

The postrigor treatment had the lowest WBP value (96.01% bound water) compared to the other prerigor ES treatments. The postrigor treatment was significantly lower ($P<0.05$) than the 180 volt prerigor ES treatment which had the highest pre-cook WBP value (98.15%), otherwise the postrigor treatment was not significantly different from any of the other prerigor ES treatments.

Pre-Cook Cellular Disruption

The cellular disruption scores for the zero voltage prerigor and postrigor-zero voltage ES treatments were not significantly different since these two treatments received no electrical stimulation and resulted in little cellular histological tissue damage. Otherwise, cellular disruption scores increased with elevated ES application, with the 270 volt prerigor ES treatment exhibiting the highest cellular tissue damage of all the treatments.

Instron Bind Force

The Instron bind force scores for the postrigor control were similar to the 90 and 270 volt prerigor ES treatments in Table 5. The 180 volt ES treatment was shown to have greater bind ($P<0.05$) than the 0, 90 and 270 volt ES treatment group and the postrigor control. The Duncan's test showed no difference ($P<0.05$) between the postrigor treatment group and the 90 and 270 volt ES prerigor treatments but a significant difference existed between the zero volt prerigor and 180 volt prerigor ES treatment. The 180 volt prerigor treatment had the highest Instron bind force measurement (215.51 gm force units), and the zero prerigor ES treatment exhibited the lowest Instron bind force value (158.56 gm force units) among the treatments.

Sensory Panel Cohesion Scores

The postrigor treatment had a sensory panel cohesion mean score which is not significantly different ($P<0.05$) from the prerigor ES treatments of zero, 180 and 270 volts. The 90 volt prerigor ES treatment had the lowest sensory cohesion score (5.74) and the 180 volt treatment had the highest (6.53) sensory cohesion score for all treatments. All sensory panel cohesion scores, with the exception of the 90 volt ES prerigor treatment were within an acceptable range of the post rigor treatment scores. Sensory panel cohesion scores were significantly correlated ($r=0.26$; $P<0.05$) with Instron bind force scores.

Sensory Panel Tenderness Scores

The postrigor treatment sensory panel tenderness mean score was not significantly different from the zero, 90 and 180 prerigor ES treatment means but was significantly more tender than the 270 volt treatment mean. All prerigor voltage ES treatment tenderness scores were above 6.28 which is within an acceptable range for tenderness.

Sensory Panel Color Distribution Scores

Prerigor voltage ES treatment means for the sensory panel color distribution were not significantly different from the postrigor treatment. This increased uniformity is probably due to the muscle tissue being cured with an automatic multiple stitch injection machine as compared to single needle stitch injection curing used in past studies at the Ohio State University meat

laboratory.

Cooked Yields

There was no difference in cooked yields among the postrigor treatment group and the prerigor ES treatments (Table 5).

CONCLUSION: From each of the significantly affected variables in this study that the 180 volt ES prerigor treatment seems to be the best prerigor ES treatment that has sufficient quality, chemical and yield characteristics of equal merit to that of a conventionally processed boneless ham. From utilizing electrically stimulated prerigor porcine muscle tissue in combination with hot processing, the procurement of cured pork products can be greatly accelerated from the hot carcass form in addition to the benefits from the economic gains of hot processing.

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TABLE 3: Least-Square Means (LSM) and Standard Errors (SE) for the Effect of Rigor Condition on the Pre-Electrical Stimulation Carcass pH, Post-Electrical Stimulation Carcass pH, pH Change of Pre-ES pH from Post ES pH, Post-Curing Ham Roast pH, Pre-Cook Ham Roast pH, Post-Cook Ham Roast pH, pH Change of Post-Cook pH from Pre-Cook pH, and 36 Hour Carcass pH

Rigor Condition	Pre				Post	
Voltage Level[a]	0	90	180	270	0	
	LSM	LSM	LSM	LSM	LSM	SE[b]
Pre-ES pH	6.24	6.16	6.28	6.17	6.23	0.03
Post ES pH[d]	6.18[e]	6.03[f]	6.00[f]	6.05[f]	6.18[e]	0.04
pH change, Pre-ES from Post ES[h]	0.06[e]	0.13[f]	0.28[f]	0.12[f]	0.05[e]	0.01
Post Curing pH[d]	6.11[e]	6.12[e]	6.00[f]	5.99[f]	5.80[g]	0.03
Pre-Cook pH[c]	5.89[e]	5.89[e]	5.83[f]	5.83[f]	5.83[f]	0.02
Post-Cook pH[c]	6.20[e,f]	6.21[e]	6.13[f,g]	6.20[e,f]	6.12[g]	0.03
pH change, Pre- & Post-Cook[h]	0.31[e]	0.32[e,f]	0.30[e]	0.37[f]	0.29[e]	0.02
36 Hour Carcass pH	5.70	5.71	5.72	5.70	5.75	0.02

[a]Stimulation applied 40-45 minutes post-exsanguination, 1.5 sec. on/1.5 sec. off for 20 impulses
[b]SE are the same across the row
[c,d]Voltage treatment significant at ($P<0.05$) and ($P<0.01$) respectively
[e,f,g]LSM with different superscripts across the row are significantly different ($P<0.05$)
[h]Significant ($P<0.05$) change in pH during ES and cooking

TABLE 4: Least Squares Means (LSM) and Standard Errors (SE) for the Effect of Rigor Condition at Curing and Electrical Stimulation Voltage on the Pre-Cook Salt Soluble Proteins (SSP), Pre-Cook Water Binding Potential (WBP; % Bound Water), and Pre-Cook Cell Disruption Score of Boneless Pre- and PostRigor Cured, Sectioned and Formed Ham Roasts

Rigor Condition @ Cure	Pre				Post	
Voltage Level[a]	0	90	180	270	0	
	LSM	LSM	LSM	LSM	LSM	SE[d]
Pre-Cook SSP[b,f]	40.58[g]	43.57[g,h]	46.83[h,i]	45.60[g,h,i]	50.14[i]	1.92
Pre-Cook WBP,[e]	96.88[g,h]	96.82[g,h]	98.15[h]	96.81[g,h]	96.01[g]	0.50
Cell Disruption Score[c,f]	1.17[g]	1.60[h]	2.04[i]	2.73[j]	1.10[g]	0.10

[a]Stimulation applied 40-45 minutes post-exsanguination at 1.5 sec. on/1.5 sec. off for 20 impulses
[b]Expressed in mg SSP/mg of sample
[c]Histological Score, 1=normal, 3=extreme cellular disruption, 2=combination of 1 and 3
[d]SE are the same across the row
[e,f]Voltage treatment significant at (P<0.05) and (P<0.01), respectively
[g,h,i,j]LSM with different superscripts are significantly different (P<0.05)

TABLE 5: Least-Square Means (LSM) and Standard Errors (SE) for the Effect of Rigor Condition at Curing and Electrical Stimulation Voltage Treatment on the Instron Bind Force, Sensory Cohesion, Tenderness, Color Distribution Scores and Cooked Yield of Boneless Pre- and PostRigor Cured, Fully Cooked, Sectioned and Formed Ham Roasts

Rigor Condition @ Cure	Pre				Post	
Voltage Level[a]	0	90	180	270	0	
	LSM	LSM	LSM	LSM	LSM	SE[e]
Instron Bind Force[b,g]	158.56[j]	164.12[i,j]	215.51[h]	176.42[i,j]	186.89[i]	9.61
Cohesion Score[c1,g]	6.26[h,i]	5.74[j]	6.53[h]	5.95[i,j]	6.46[h,i]	0.19
Tenderness Score[c2,g]	6.78[h]	6.40[i,j]	6.53[h,i,j]	6.28[j]	6.74[h,i]	0.12
Color Distrib. Score[c3]	5.71	5.24	5.50	5.49	5.56	0.22
Cooked Yield, %[d]	86.30	87.32	87.24	87.86	87.61	0.48

[a]Stimulation applied 40-45 minutes post-exsanguination at 1.5 sec. on/1.5 sec. off for 20 impulses
[b]Instron force measurement, expressed in peak force (grams)
[c1]Sensory panel score, scored on a scale of 1-9, 1=extremely noncohesive and 9=extremely cohesive
[c2]Sensory panel score, scored on a scale of 1-9, 1=extremely tough and 9=extremely tender
[c3]Sensory panel score, scored on a scale of 1-9, 1=extremely uneven and 9=extremely even/uniform
[d](Post-cook weight/pre-cook weight) x 100
[e]SE are the same across the row
[f,g]Voltage treatment significant at (P<0.05) and (P<0.01), respectively, among prerigor ES treatments
[h,i,j]LSM with different superscripts are significantly different (P<0.05)