EFFECTS OF STRESS-SUSCEPTIBILITY OF HOGS AND PROCESSING TREATMENTS ON THE QUALITY OF PORK PRODUCTS

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SUMMARY

The results of this experiment suggest an optimal method for handling pork from halothane positive (stress susceptible or PSS+) hogs in the production of meat products. The highest cooked yields and most desirable sensory characteristics for Canadian-style bacon, made from PSS+ pork muscle, resulted when the pork was injected in the prerigor state, with a curing pickle containing a sodium tripoly-/hexametaphosphate mixture (STPP).

Pork from PSS+ hogs also resulted in lower ham and cooked sausage smokehouse yields. This indicates that pork from PSS+ hogs does have detrimental effects on the processing characteristics of shoulders as well as hams. The addition of STPP improved ham smokehouse yields and soy isolates increased consumer cook test yields for cooked sausage. However, this study was not able to show any differences in bacon frying yields due to the rigor state of, or phosphate addition, to bellies.

INTRODUCTION

The U.S. meat industry is still plagued with the PSE problem despite research efforts that began well over 20 years ago. Much of the earlier pork quality research has concentrated on genetics and the Porcine Stress Syndrome (PSS) (Topel et al., 1968). Little work has been done on processing procedures which might compensate for the reduced quality of PSE pork. With the recent interest in the quality-conscious Japanese market and the advent of fewer processed meat companies doing their own slaughtering, PSE has reemerged as a serious quality issue in the United States.

The processing of meat prerigor may be a method of controlling the two major factors in the development of PSE, rapid pH drop and high muscle temperature. Troeger and Woltersdorf (1987) reported that 4% higher yield was obtained from hams and shoulders made from prerigor meat and they were superior to hams made from conventional postrigor meat in regard to cured color development, tenderness and juiciness. Results have also indicated that prerigor processed meat exhibited higher pH, water-holding capacity (WHC) and cooked yield characteristics (Motycka and Bechtel, 1983).

Alkaline phosphates (Knipe et al., 1985) are non-meat ingredients used for increasing the WHC of meat. However, there has been some debate over the efficacy of adding inorganic phosphates to prerigor meat (Streitel et al., 1977; Kamstra and Saffle, 1959). van Laack et al. (1989) reported that the addition of phosphates to pickles which were intended for use in hot-processing was a requirement when expecting yields similar to traditionally processed products. On the other hand, Troeger and Woltersdorf (1987) stated that there was no need to add water or fat binding agents to pre-rigor meat because it still contains the natural phosphate, ATP.

Therefore, the purpose of this study is to compare the effects of pre- versus postrigor processing, combined with the addition of STPP on improving the cooked yields and sensory characteristics of boneless Canadian-style bacon, ham and belly bacon made from PSS^{+} and halothane negative (stress resistant or PSS^{-} hogs. The effects of STPP and soy isolates on cooked sausage yields were also investigated.

MATERIALS AND METHODS

Six PSS^{+} and six PSS^{-} hogs were obtained from the Iowa State University Research Farm for each of the four replications. Hogs were delivered to the Iowa State University Meat Laboratory just prior to slaughter. Immediately after slaughter, one side of each carcass was boned in the prerigor state at 35°C within 30 min postmortem. The other side of each carcass was chilled at 1.7°C for 24 hr.

Loins, hams and bellies were pulled from the pre-rigor sides of 3 PSS+ and 3 PSS- hogs. The loins and hams were injected to 125% of their initial weight within 60 minutes postmortem by using a Model 1400 Townsend injector. Two pickles were used, a control, which contained 11.25% salt, 2.25% sugar, 0.07% sodium nitrite and 0.25% sodium erythorbate, plus a second pickle which contained an additional 1.8% STPP. Muscle temperature and time postmortem were recorded for the pre-rigor loins at the time of injection. Injected loins and hams were loaded into a vacuum tumbler, tumbled for 20 minutes and rest 40 minutes of every hr for 24 hr at 1.7°C, stuffed into fibrous casings, weighed, smoked and cooked in a smokehouse to an internal temperature of 68°C, chilled overnight, and reweighed 14 hours later to obtain cooked yields based on the pumped weight. The following day, the same treatments were applied to the remaining postrigor sides which were conventionally chilled for 24 hr at 1.7°C.

Bellies were injected to 111% of their initial weight within 60 min postmortem by using two pickles-a control, which contained 22.7% salt, 4.5% sugar, 0.114% sodium nitrite and 0.5% sodium erythorbate, plus a second pickle, which contained an additional 3.6% STPP. Injected bellies were weighed, smoked and cooked in a smokehouse to an internal temperature of 54°C, chilled overnight, reweighed 14 hr later to obtain cooked yield based on pumped weight, skinned and sliced. The following day the same treatments were applied to the remaining postrigor bellies which were conventionally chilled for 24 hr at 1.7°C before processing.

Twenty four hours after slaughter, postrigor shoulders were deboned for production of cooked sausage. The meat from 2 hogs of similar genotype were combined, ground through a 12.7-mm grinder plate and mixed with the appropriate non-meat ingredients. Cooked sausage treatments consisted of a control (which contained 20.0% water, 2.5% salt, 0.25% modern cure, 0.055% sodium erythorbate and 0.5% seasoning), a soy isolate treatment (which contained 20.0% water, 2.5% salt, 2.0% soy isolate, 0.25% modern cure, 0.055% sodium erythorbate and 0.5% seasoning) and a STPP treatment (which contained 20.0% water 2.5% salt, 0.5% STPP, 0.25% modern cure, 0.055% sodium erythorbate and 0.5% seasoning). After blending, the blends were reground through a 4.8-mm grinder plate, stuffed into 34-mm collagen casings, weighed, smoked and cooked in a Maurer and Sohne smokehouse to an internal temperature of 68°C, chilled overnight and reweighed 14 hr later to obtain cooked yields.

Color analysis of the samples was performed with a Hunterlab Labscan Spectrocolorimeter (Hunter Associates Laboratories Inc., Reston, Va.). Illuminant F, representing cool white fluorescent lamplight, and a 17 mm sample port insert was selected for all readings. The instrument was standardized with a white tile [X=81.60, Y=86.68, Z=91.18]. Values from 6 samples per treatment were averaged to give one "L", "a" or "b" value per treatment.

Texture measurements were made by using an Instron Universal Testing Machine (Instron Corp., Canton, Ma.) equipped with a Warner-Bratzler Shear (WBS) apparatus. The Instron was set up with a 500-Kg loadcell, full scale load of 1.0, crosshead speed of 100 mm/min and the chart speed at 200 mm/min. Results are expressed as Kg of force required to shear a 15-mm diameter core sample of Canadian bacon perpendicular to the muscle fibers. Six measurements on 3 samples were taken.

Cooked Canadian bacon was evaluated by an untrained consumer sensory panel consisting of 20 panelists per replication. Color, flavor, tenderness, juiciness, and overall acceptability of unheated Canadian bacon slices were scored using a 7-point hedonic scale in which "7" signifies extremely desirable, flavorful, tender or juicy, and "1" is equivalent to extremely undesirable, tough, dry, bland and/or unacceptable.

The consumer cook (reheating) test for the cooked sausage was measured using the Tauber and Lloyd (1947) method, as modified by Frye et al. (1990).

Frying tests on 1-mm thick bacon slices were performed by cooking 230-g of bacon slices on a griddle, preheated to 176.6°C, for 3 min per side. Fried bacon slices were then allowed to cool to room temperature on paper towels and weighed. Percent frying yield was calculated by dividing the fried bacon weight by the initial weight.

Shrinkage in length of the cooked bacon slices was determined by measuring the length of the 1-mm bacon slices taken from the center of the belly, cooking the slices on a griddle, preheated to 176.6°C, for 3 min per side. Fried bacon slices were then allowed to cool to room temperature and length was remeasured. Percent cooking shrink was calculated by dividing the length of the fried bacon by the initial length.

The ranges of the bacon color were calculated by taking the "L", "a" and "b" values of the darkest lean area of the bacon slice and subtracting the "L", "a" and "b" values of the lightest lean area of the bacon slices.

The Statistical Analysis System (SAS, 1986) was used to determine means, standard errors and analysis of variance. Duncan's multiple range test was used to separate the means. For each sensory panel session, data were averaged over all panelists before analysis. An alpha level of 0.05 was used to determine significance. The experiment was replicated 4 times.

RESULTS AND DISCUSSION

Canadian-style cooked yields were shown to be significantly ($P<0.01$) higher for cooked Canadian bacon produced from PSS- pork loins and for the Curafos treatments (Table 1). The shear force values of the Canadian-style bacon, made from PSS+ hogs, were significantly ($P<0.05$) higher that that made from PSS- hogs (Table 1). Rigor state and addition of STPP did not affect shear force values.

Hunter Color Lab values (Table 1) were significantly ($P<0.05$) affected by phosphate treatments and genotype but not by rigor state. The phosphate treatments had lower "L" values and higher "a" values. The PSS+ loins also had significantly ($P<0.05$) higher "b" values than the PSS- loins.

Only the four phosphate treatments were evaluated by a consumer sensory panel due to the poor cooked yields of the no-phosphate treatments. Canadian-style bacon made from the PSS- loins was significantly ($P<0.01$) more desirable in flavor and overall acceptability and significantly ($P<0.05$) more desirable in texture than Canadian-style bacon made from the PSS+ loins (Table 2). The preferred texture was found to be with product made from the PSS- hogs. The study by Honkavaara (1989) also reported that cured hams produced from PSE muscle had lower texture and overall acceptability scores.

The consumer sensory panel preferred ($P<0.01$) the flavor of the product from the prerigor loins over the product made from postrigor loins. The prerigor loins also resulted in significantly ($P<0.05$) lower shear force values. This agreed with the findings of Kastner (1982) who also found prerigor loins to have lower shear force values.

After examining the effects of genotype, rigor state and phosphate addition, the eight treatment combinations were compared (Table 3). The comparison of all treatments in this experiment showed that the loins from the PSS- hogs, injected with a pickle containing phosphates, resulted in the highest cooked yieldsm, regardless of the rigor state. However, the loins injected with phosphate during the prerigor state resulted in the best cooked yields. The treatment involving postrigor PSS- loins injected with a pickle containing STPP was considered the most conventional processing procedure. The conventional processing resulted in cooked yields that were not significantly ($P>0.05$) different from the PSS- loins injected with phosphate prerigor or the PSS+ loins injected prerigor with STPP.

Hams made from PSS- hogs had significantly ($P<0.01$) higher smokehouse yields than the hams from PSS+ hogs (Table 1). Honkavaara (1985 and 1989) also found that hams from PSS+ hogs had lower water-holding capacity (WHC) than PSS- hogs and that PSE muscle had lower smokehouse yields than hams from normal muscle.

Rigor state of the pork muscle had no significant effect on ham smokehouse yields (Table 1). Mandigo et al. (1977) also reported no difference in yields between prerigor and conventionally or cold-processed hams. However, this disagrees with Motycka and Bechtel (1983) who found prerigor meat to have higher cooked yields than conventionally-processed meat.

STPP treatment had a significant ($P<0.05$) effect on ham smokehouse yields (Table 1). This is in contrast to Honkavaara (1989) who found that the addition of phosphates did not improve the WHC of PSE meat.

Bacon smokehouse yields were not significantly (P>0.05) affected by genotype, rigor state or phosphate treatment (Table 1). This would agree with Taylor et al. (1982) who also found that rigor state had no effect on processing yields of bacon.
Bacon frying yields and bacon shrinkage was not significantly (P>0.05) affected by genotype, rigor state or phosphate treatments (Table 1). These findings also agree with Taylor et al. (1982) who found processing procedures did not affect bacon smokehouse yields. Abu-Bakar et al. (1983) also reported that the decrease in bacon strip length during cooking was not affected by prerigor processing treatments. In contrast, Jeremiah (1986) did find greater cooking losses of bacon slices from PSE bellies.

The range of Hunter "L" values for bacon were significantly (P<0.01) affected by STPP treatments. The phosphate treatment had a lower range in "L" reading than the no STPP treatment indicating more uniform cured color development. The "a" and "b" ranges were not affected by the genotype, rigor state or STPP treatment.

Cooked sausage smokehouse yields were affected by genotype and the non-meat ingredient treatment that included soy isolates (Table 4). The cooked sausage from PSS$^+$ hogs had significantly (P<0.05) lower smokehouse yields than sausage from PSS$^-$ hogs. This is in agreement with Wirth (1986) who found PSE meat used in processed meat products to have higher cooking losses than normal quality pork muscle. The soy isolate treatment also had significantly (P<0.05) higher smokehouse yields than the control. The consumer cook test yields were significantly (P<0.05) higher for the soy isolate and STPP treated sausages (Table 4).

Hunter color Lab values for cooked sausage were not affected by genotype but were affected by the addition of non-meat ingredients (Table 4). The "L" values were significantly (P<0.05) higher for the control than for the STPP treatment. Even though the "L" values for the control treatment were higher than the STPP, the differences could not be determined visually. The "a" and "b" values of the cooked sausage were not affected by neither the genotype nor non-meat ingredient treatments.

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Table 1--Effects of genotype[1], rigor state and phosphate treatments[2] on cooked characteristics of Canadian-style bacon, ham and belly bacon.

	Canadian-style bacon						Ham	Belly bacon					
		Cooked	Shear	Hunter Color Values[4]			Cooked	Cooked	Frying		Hunter color ranges[6]		
Treatment	pH	Yield (%)	Force[3]	L	a	b	Yield (%)	Yield (%)	Yield (%)	Shrink (%)[5]	L	a	b
PSS+	5.93**	85.33**	2.66*	62.95	6.37	6.30*	83.15**	87.92	33.74	64.36	9.93	1.46	0.48
PSS-	6.10	88.96	2.05	62.40	6.21	5.82	86.88	89.53	33.97	64.16	9.53	1.99	0.15
prerigor	6.05	87.86	2.27	62.78	6.28	6.08	86.65	86.94	35.13	64.85	10.86	2.10	0.33
postrigor	6.00	86.42	2.44	62.56	6.30	6.04	83.38	90.54	32.92	64.25	8.61	1.35	0.31
Control[2]	5.98	85.21**	2.41	63.62*	6.20*	6.30*	82.39**	86.04	34.50	63.97	11.96**	2.05	0.23
STPP	6.06	89.09	2.30	61.72	6.38	5.82	87.64	91.45	33.27	64.16	7.51	1.40	0.40
S.E.	0.04	0.62	2.02	0.48	0.05	0.11	0.41	1.78	0.58	0.83	0.94	0.22	0.10

[1]PSS+=pork from halothane positive (stress susceptible) hogs.
PSS-=pork from halothane negative (stress resistant) hogs.

[2]0.5% Sodium tripoly- and hexametaphosphate mixture (STPP).

[3]Warner-Bratzler shear force in Kg.

[4]L value: 0=black, 100=white; a value: +=red, -=green; b value: +=blue, -=yellow.

[5]Bacon shrink determined by dividing the length of cooked slices from the center of each belly by the length of the raw slices.

[6]Ranges determined by the difference between Hunter Lab values of the darkest lean portions and the lightest lean portions of the bacon.

*Significant ($P<0.05$).

**Highly significant ($P<0.01$).

Table 2. Effects of hog genotype[1] and rigor state of pork muscle on sensory evaluation[2] and shear values[3] of cooked Canadian-style bacon

Treatments	Sensory Evaluation: Color	Tenderness/ Juiciness	Flavor	Overall Acceptability	Shear Force
PSS+	4.90	4.53*	4.60**	4.53**	2.52*
PSS-	5.06	5.12	5.13	5.08	2.08
Prerigor	5.00	4.83	4.98**	4.92	2.07*
Postrigor	4.97	4.82	4.75	4.70	2.53
Standard error	0.15	0.11	0.03	0.09	2.37

[1]PSS+=pork from halothane positive (stress susceptible) hogs.
PSS-=pork from halothane negative (stress resistant) hogs.
[2]Seven-point hedonic scale: 7=extremely desirable, 1=extremely undesirable.
[3]Warner-Bratzler shear force in Kg.
*Significant (P<0.05).
**Highly significant (P<0.01).

Table 3. Comparison of the effects of hog genotype[1], pork muscle rigor state and phosphate[2] addition on cooked yield of cooked Canadian-style bacon

Treatments	% Cooked Yield[3]
PSS-/prerigor/STPP	91.34[a]
PSS-/postrigor/STPP	89.53[a,b]
PSS+/prerigor/STPP	88.75[a,b]
PSS-/prerigor	88.69[a,b]
PSS+/postrigor/STPP	86.69[b,c]
PSS-/postrigor	86.28[b,c]
PSS+/postrigor	83.19[c]
PSS+/prerigor	82.69[c]
Standard error	0.51

[1]PSS+=pork from halothane positive (stress susceptible) hogs.
PSS-=pork from halothane negative (stress resistant) hogs.
[2]0.5% sodium tripoly- and hexametaphosphate mixture (STPP).
[3]Mean values of cooked yields in a column followed by a different letter (a,b,c) are significantly different (P<0.05).

Table 4. Effects of genotype[1] and non-meat ingredient treatments on smokehouse, "consumer cook" test yields and Hunter color Lab[2] values of cooked sausage

Treatment	Smokehouse Yield (%)	Consumer Cook Test Yield (%)	L	a	b
PSS+	85.68*	98.13	52.17	6.10	6.58
PSS-	87.06	97.85	52.62	5.94	6.57
Standard error	0.43	0.14	0.38	0.11	0.11
Control	85.57[b]	97.37[b]	53.29[a]	6.03	6.53
Soy Isolate	87.33[a]	98.36[a]	52.25[a,b]	6.02	6.75
STPP[3]	86.21[a,b]	98.24[a]	51.72[b]	6.01	6.44
Standard error	0.53	0.17	0.46	0.13	0.14

[1]PSS+=pork from halothane positive (stress susceptible) hogs.
PSS-=pork from halothane negative (stress resistant) hogs.
[2]L value: 0=black, 100=white; a value: +=red, -=green; b value: +=blue, -=yellow.
[3] 0.5% sodium tripolyphosphate.
[a,b]Mean values in the same column bearing like or no superscripts are not different ($P>0.05$).
*Significant ($P<0.05$).
**Highly significant ($P<0.01$).