Restructuring of Hot-Processed Meat

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Introduction

In recent years, two of the areas of meat processing that have received considerable attention are the manufacture of fresh restructured meats and pre-rigor or hot processing. Restructuring allows us to take lower economic value cuts or carcasses and through manufacturing techniques upgrade these raw materials into desirable meat products of a uniform size, shape and texture (Huffman, 1979).

In this manuscript, I shall confine my comments to fresh restructured meat products. This will then exclude from discussion restructured products processed with the addition of nitrite. I will make one exception to this later when I discuss a study conducted at Auburn University in which encapsulated food acids were used to produce a pseudo country ham product from pre-rigor sow meat.

In the last 3 to 5 years, we have seen an increased demand in the hotel, restaurant and institutional trade for restructured meat. This demand is expected to increase steadily over the next 10 years. In 1981 and 1982, I attended the National Restaurant Association trade show at McCormick Place in Chicago to visit with people in the HRI trade about restructured meats. On both occasions, I was impressed and almost overwhelmed by the enthusiasm of these people for this type of product. They find products that are consistent in quality, size and price to be highly desirable.

While restaurant personnel have been looking for high-quality meat products, the meat industry has been searching for more economical ways to produce these products. Pre-rigor or hot processing seems to hold considerable potential as a way in which the meat industry can become more efficient. Henrickson (1981), Kastner (1977) and Bowling (1981) all discussed potential economic advantages with pre-rigor processing. It has been estimated that to chill just the edible portion of a 600 lb beef carcass after excess fat and bone had been removed would require 24% less energy than chilling the entire carcass. Cooler space required to chill the edible portion may be as much as 80% less than required for a bone-in carcass (Henrickson, 1981). In recent years, we have started to see packers, like Tennessee Dressed Beef, taking advantage of some of these economic opportunities. In the late 1970's, they inaugurated one of the first U.S. on-the-rail hot-boned beef operations which greatly reduced their need for carcass coolers (Anonymous, 1978).

The literature on manufacture of restructured meats from pre-rigor meat is limited so it is helpful to look at literature dealing with the pre-rigor processing of finely comminuted products, such as ground beef, pork sausage and pork patties, to get a feel for what is possible with restructured products manufactured from pre-rigor meat. Finely comminuted products contain much smaller meat particles than restructured products, but the basic principles are similar so much of the information is transferable. Before discussing the manufacture of products from pre-rigor meat, I would like to review briefly what takes place during postmortem glycolysis in pre-rigor muscle.

Postmortem Glycolysis in Pre-rigor Muscle

Dalrymple and Hamm (1975), Tarrant (1977) and Marsh (1981) have discussed the properties and behavior of pre-rigor meat. Hamm (1977) presented an excellent review on the postmortem breakdown of ATP and glycogen in ground muscle. He reported that pre-rigor grinding caused an accelerated hydrolysis of ATP and ADP, which resulted in a faster increase in the IMP concentration and in an accelerated glycolysis. This increase in the turnover of ATP as a result of pre-rigor grinding may be due to a faster release of CA^{++} ions from the damaged sarcoplasmic reticulum. An addition of 2% to 4% salt (sodium chloride) to the ground pre-rigor muscle caused an increase in the rate of breakdown of ATP to IMP. After several hours postmortem, an inhibition of glycolysis was observed in the salted tissue, probably as a result of the combined effects of low pH (<6) and high ionic strength. The high water-holding capacity of salted ground beef does not decrease postmortem even with the high rate of ATP breakdown. This can be explained on the basis that rigor mortis is inhibited in the fiber fragments as a result of the combined effects of ATP, pH and salt concentration.

Pre-rigor Processing of Ground Beef

Cross et al. (1979), Nusbaum (1979) Wells et al. (1980) and Jacobs and Sebranek (1980) investigated the use of pre-rigor muscle for ground beef. They reported that acceptable ground beef can be manufactured from pre-rigor meat. Generally the ground beef manufactured from the pre-rigor meat was more tender and juicy and had a lower percent cooking loss than product produced from chilled meats. When fabrication of pre-rigor beef carcasses into steaks and roasts becomes an accepted practice in the meat industry, it is likely that these carcasses will be electrically stimulated. Cross and Tennet (1981), Contreras et al. (1981) and Berry and Stiffler (1981) looked at the effects of electrical stimulation in ground beef manufactured from pre-rigor meat. Generally, these researchers found that electrical stimulation had no adverse

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effect on the physical, sensory or cooking properties of ground beef patties. However, Contreras et al. (1981) did report higher cooking losses in ground beef manufactured from electrically stimulated hot-boned sides compared to that manufactured from conventionally chilled sides.

Emswiler and Kotula (1979) and McMillin et al. (1981) reported little difference in the microbial quality of ground beef processed from hot and chilled beef carcasses. Raccach and Henrickson (1978) reported an increase in shelf life of 3 days for ground beef manufactured from hot-boned, electrically stimulated carcasses when compared to product manufactured from non-stimulated, hot-boned sides.

Pre-rigor Processing of Pork Sausage and Pork Patties

Lin et al. (1979) and Drerup et al. (1981) observed that pork sausage manufactured from pre-rigor muscle had higher pH values, lower cooking losses and higher juiciness scores when compared to that processed from post-rigor muscle. However, Lin et al. (1979) did report higher bacterial counts for the pre-rigor sausage.

Judge and Aberle (1980) investigated the effect of pre-rigor grinding on development of oxidative rancidity in ground pork. They reported that samples ground in the pre-rigor state were less susceptible to autooxidation than post-rigor ground samples. The addition of salt increased the TBA values with the prooxidant effect of salt (Chang and Watts, 1950; Ellis et al., 1968) being more pronounced in the post-rigor than the pre-rigor samples. Similar results were reported by Drerup (1979). Judge and Aberle (1980) also reported that pre-rigor oxygenated light muscles were more susceptible to oxidation than dark muscles. Chiang et al. (1981) reported that, in general, vacuum packaging is required to maximize the advantage of retarding lipid oxidation in pre-rigor processing.

Pre-rigor Processing of Poultry

Furumoto and Stadelman (1980) investigated the effect of pre-rigor processing and salt addition on poultry rolls manufactured from either chicken or turkey meat. They reported that, regardless of rigor state, addition of salt significantly improved tenderness. Unsalted hot-boned chicken rolls were more tender than unsalted cold-boned chicken rolls. In contrast, hot-boned turkey rolls were less tender than cold-boned rolls. Kardouche and Stadelman (1978) found no significant differences due to rigor state in turkey rolls containing 1.5% salt.

Manufacture of Restructured Meats from Pre-Rigor Meat

Pepper and Schmidt (1975) compared beef rolls manufactured with either hot-boned or cold-boned beef rounds. They examined the beef rolls for differences in shear, cook yield and chemical composition (Table 1). The hot-boned rolls had higher cook yields and lower binding strengths than the cold-boned rolls. However, the hot-boned rolls were very acceptable from a firmness and textural standpoint. Hot-boning the meat did not alter the chemical composition of the rolls. Overall, they felt that the hot-boned rolls were more desirable due to differences both in processing and yield.

Table 1. The Effect of Hot-Boned Meat on Properties of Beef Rolls*

		Mix time min	*Instron g/cm²*	*Cook yield %*	*Water %*	*Fat %*	*Protein %*	*Phosphorus %*	*Sodium chloride %*
Salt 1%	Hot	5	149	88.4	66.7	11.5	20.3	0.15	1.2
		10	187	88.0	64.4	13.3	20.5	0.16	1.1
		20	236	88.8	65.1	12.5	20.4	0.16	1.3
	Cold	5	221	77.9	63.8	13.1	18.2	0.14	1.2
		10	293	78.8	63.9	13.3	19.7	0.15	1.1
		20	314	78.4	65.6	10.1	20.9	0.15	1.1
Salt (1%)	Hot	5	255	92.2	63.7	16.4	17.7	0.20	1.6
Phosphate (0.25%)		10	297	92.6	66.8	11.5	19.9	0.22	1.6
		20	317	95.3	67.5	11.5	17.9	0.22	1.7
	Cold	5	372	84.5	64.0	14.1	19.4	0.20	1.4
		10	294	84.0	64.8	12.5	19.7	0.19	1.3
		20	433	86.3	65.7	11.4	19.4	0.20	1.3
Overall mean									
Salt	Hot		190[b]	88.4[b]	65.4	12.4	20.4	0.16	1.2
	Cold		276[b]		78.4[b]	64.4	12.1	19.6	0.15
1.1									
Salt-Phosphate	Hot		290[a]	93.4[b]	66.0	13.1	18.5	0.21	1.6
	Cold		367[a]	84.9[b]	64.9	12.7	19.5	0.20	1.3

[a]Significant difference at the 5% level between rolls prepared with hot- and cold-boned meat.
[b]Significant difference at the 1% level.
*Pepper and Schmidt, 1975.

Table 2. Mean Values for Sensory Attributes of Restructured Steaks*

Boning treatment	Slice thickness	*Sensory attributes*^{a} Juiciness^{b}	Tenderness^{c}	Texture desirability^{d}	Texture description^{e}	Flavor desirability^{d}	Overall palatability^{d}
Intact steaks		6.0^{f}	5.4^{fg}	5.6^{f}	4.4^{g}	6.2^{f}	6.0^{f}
Hot-boned	5.0 mm	3.9^{g}	3.4^{h}	3.8^{h}	5.3^{f}	5.0^{g}	3.9^{h}
	2.5 mm	4.6^{g}	4.9^{fg}	4.7^{g}	4.3^{g}	5.0^{g}	4.7^{g}
Aged	5.0 mm	4.3^{g}	4.7^{g}	4.8^{g}	4.4^{g}	5.7^{f}	5.0^{g}
	2.5 mm	4.2^{g}	5.8^{f}	5.5^{f}	3.6^{h}	5.7^{f}	5.3^{fg}

^{a}Means in the same column followed by a common letter (f, g, h) are not different ($P<0.05$).
^{b}Means based on an 8-point scale (8 = extremely juicy; 1 = extremely dry).
^{c}Means based on an 8-point scale (8 = extremely tender; 1 = extremely tough).
^{d}Means based on an 8-point hedonic scale (8 = like extremely; 1 = dislike extremely).
^{e}Means based on a 7-point scale (7 = extremely tough or rubbery; 4 = excellent; 1 = extremely mushy or crumbly).
*Seideman et al., 1982.

Seideman et al. (1982) examined the effects of hot-boning and particle thickness on restructured beef steaks. In this study, inside and outside rounds were used for raw material with the hot-boned rounds boned 3 hr postmortem and the cold-boned rounds boned 10 days postmortem. Both the hot-boned rounds and the cold-boned rounds were frozen at −20°C for 3 days prior to being manufactured into restructured steaks. Steaks were manufactured both from 2.5 mm and 5.0 mm thick slices. They observed no differences in the textural properties of deformation (index of elasticity) and stress (index of strength) due to treatment. However, steaks manufactured with 5.0 mm slices required significantly more energy to shear than steaks manufactured with 2.5 mm slices. (Note: These textural determinations were made with a PEP Texture Tester Model TT2 supplied by PEP Inc., Houston, Texas.) Sensory data for these steaks is shown in Table 2. They concluded that hot-boned beef resulted in less tender restructured steaks of lower flavor and texture desirability than steaks manufactured from aged beef. Steaks manufactured from 5.0 mm slices were less desirable, both from an objective and subjective standpoint, than steaks manufactured from 2.5 mm slices.

Several studies have been conducted at Auburn University in which restructured products have been produced in which either all or part of the meat block was pre-rigor. In one study, restructured pork chops were manufactured from pre-rigor hams and sirloin ends blended with frozen and tempered Boston butts (Huffman and Cordray, 1979). These restructured products were compared with boneless pork loin chops sliced from loins which were excised from the carcasses and frozen at 1½ hrs postmortem. These loins came from the same carcasses that supplied the pre-rigor hams and sirloin ends. Sensory evaluation, cooking loss and Instron scores for this study are shown in Table 3. There were no significant differences among the restructured pork chop treatments for tenderness, juiciness, connective tissue and flavor. The boneless pork loin chops were significantly less desirable than restructured chops for the sensory attribute tenderness. The boneless pork loin chops were somewhat lower in juiciness than restructured pork chops, but not significantly different from those containing no additives and the salt treatments. Pork loin chops had a higher ($P<0.05$) score for connective tissue, reflecting the lack of desired tenderness. The addition of TPP, alone or in combination with salt, affects juiciness. Pork loin chop color ratings were significantly higher than all restructured products except the salt plus TPP treatment.

Cooking loss was significantly higher for control restruc-

Table 3. Sensory Evaluation, Cooking Loss and Instron Scores for Pre-Rigor Pork Chops^{a,b,c,d}*

Treatment	*Sensory panel evaluation*^{e} Tenderness	Juiciness	Connective tissue	Flavor	Color	Cooking loss %	Instron^{f} Compression	Tension
No additives	6.47^{a}	5.47^{ab}	5.87^{a}	5.97^{a}	4.45^{b}	27.9^{a}	297.2^{b}	0.23^{c}
Salt (0.75%)	6.50^{a}	5.87^{ab}	5.63^{a}	6.03^{a}	4.40^{b}	20.1^{c}	246.6^{c}	0.34^{ab}
TPP (0.25%)	5.87^{a}	5.60^{a}	5.63^{a}	6.07^{a}	4.65^{b}	23.9^{b}	270.8^{bc}	0.29^{bc}
Salt (0.75%) + TPP (0.25%)	6.40^{a}	6.20^{a}	5.43^{a}	6.23^{a}	5.00^{ab}	14.8^{d}	228.8^{c}	0.43^{a}
Pork loin chops	4.20^{b}	4.43^{b}	6.77^{b}	5.37^{a}	6.55^{a}	18.6^{c}	349.6^{a}	—
Standard deviation	0.75	0.72	0.36	0.62	0.61	2.58	31.92	0.046

^{a,b,c,d}Means in the same column with the same superscript letter are not significantly different ($P<0.05$)
^{e} 1 = extremely undesirable; 8 = extremely desirable
^{f} = kg force
*Huffman and Cordray, 1979.

tured chops than all other treatment groups. Addition of TPP alone lowered the cooking loss ($P<0.05$) and the addition of salt alone resulted in a decrease ($P<0.05$) over TPP alone, but not significantly different from pork loin chops. When salt and TPP were combined, the cooking loss (14.8%) was significantly lower than all other treatment groups. There appeared to be a slight synergistic effect of TPP and salt in this study, which concurs with reports by Neer and Mandigo (1977), Shults and Wierbicki (1973) and Schnell et al. (1970).

Instron compression scores for pork loin chops confirmed sensory panel evaluation that pork loin chops were less tender than restructured products. Control restructured chops had lower ($P<0.05$) compression ratings than chops containing salt or salt plus TPP, but were not different from chops containing TPP only.

Huffman et al., (1983) compared restructured steaks manufactured from paired hot-boned (HB) and conventionally chilled (CB) beef carcass sides that averaged good Yield Grade 2. Salt was added to one half of each treatment at the rate of 0.75%. The fat content was pre-formulated to approximately 12% and the meat was blended for 15 minutes prior to stuffing. In triangle tests, panelists could not determine between rigor state (Table 4). However, the panel had little difficulty in determining differences between salted and unsalted restructured steaks, regardless of the state of rigor prior to processing. Panelists preferred the products prepared with salt over those without salt in both hot and cold-boned treatment groups. This agrees with the results of Cross and Stanfield (1976).

Sensory data for this study (Table 5) indicates that there were significant differences due to treatment for flavor, texture, overall acceptability and discoloration. Panelists rated the average flavor of the cold-boned products superior to hot-boned ($P<0.05$). In both rigor states, salted treatments were rated superior to unsalted products for flavor, textural properties and overall acceptability. However, salted products were the least desirable for color evaluation of all treatments. The presence of salt in a meat product lowers the pH and increases myoglobin oxidation by four or five times (Brooks, 1939).

Auburn University has also completed three studies in which the entire meat block used in the restructuring process

Table 4. Triangle Tests for Restructured Beef Steaks*

Comparison	*Number of Observations*	*Number of Correct Observations*	*Percentage Correct Observations*	*Level of Significance*
Cold, salt[1] vs. hot[2], salt	48	17	35	NS
Cold, salt vs. cold, no salt	48	36	75	.01
Hot, salt vs. hot, no salt	48	34	71	.01
Hot, no salt vs. cold, no salt	48	17	35	NS

[1]cold = chilled for 48h at 2°C prior to processing.
[2]hot = hot-boned and processed.
*Huffman et al., 1983

Table 5. Effect of Hot-Boning on Sensory Evaluation and Color Ratings of Intact Strips and Restructured Beef Steaks*

		Sensory properties[z]			*Color ratings*	
	Treatment group	*Flavor*	*Texture*	*Overall Acceptability*	*Discoloration*	*Overall Desirability*
	HBS	5.65	4.17[ab]	4.69	7.08[a]	6.88[a]
	HBRS	5.40	5.15[ac]	5.15	6.00[b]	3.46[b]
	HBRN	4.50	4.10[b]	4.19	6.29[b]	3.46[b]
Hot-boned $\bar{X}$		5.18[1]	4.47[1]	4.67[1]	6.46[1]	4.60[1]
	CBS	6.33	5.81[c]	5.92	6.08[b]	6.00[a]
	CBRS	5.73	5.23[c]	5.40	5.08[b]	2.79[b]
	CBRN	5.19	4.77[a]	4.73	6.44[ab]	3.85[b]
Cold-boned $\bar{X}$		5.75[2]	5.27[2]	5.35[2]	5.87[2]	4.22[1]

[1,2]average means (X) within a column with different superscripts are significantly different ($P<0.05$).
[a,b,c,d]means within a column with different superscripts are significantly different ($P<0.05$).
[z]8 = extremely desirable; 1 = extremely undesirable.
*Huffman et al., 1983

was pre-rigor sow meat (Cordray, 1983). In the first study, the effect of mechanical tenderization was investigated. This study was conducted in a commercial operation utilizing sows of the type used in whole-hog sausage manufacture. Approximately 30 minutes after exsanguination, the carcasses were boned in such a manner as to leave the lean/fat mass from each side of the carcass intact. The lean/fat mass was then transported to the processing room where the lean/fat mass from one side of the carcass was cut into four approximately equal-sized pieces and tenderized with a Bettcher model TR-2 blade tenderizer set at a belt advance setting of 2.54 cm. After mechanical tenderization, chunks of lean muscle were removed from the tenderized lean/fat mass and ground once with a size #52 Toledo grinder equipped with a 3 hole kidney plate and designated as the lean chunk component of the manufacturing meat block. The remainder of the lean/fat mass was ground once through a 3.18 mm plate on a size #52 Toledo grinder and designated as the fine ground component of the manufacturing meat block.

The opposite side of the carcass was handled in the same manner except that it received no mechanical tenderization. One and one-half hours postmortem, the two components of the meat block were blended for 15 minutes in a paddle mixer. After blending, the product was stuffed into 90 mm diameter fibrous casings, placed in a heat processing oven and fully cooked (68°C) with a cooking cycle of 4½-5 hours. After cooking, the product was showered to an internal temperature of 32°C, placed in a 3°C holding cooler for 12 hours and weighed to calculate a chilled yield.

Panelists detected no differences in cohesiveness, juiciness, connective tissue or flavor between the tenderized and non-tenderized treatments. Table 6 shows that there were no significant differences among treatments for shear value or percent cookloss, however, tensile strength was greater ($P<0.06$) for the tenderized than for the non-tenderized treatment. This finding is in agreement with the report of Huffman (1979) and is important because we are trying to achieve a bind in restructured products which will simulate a muscle cut.

Miller (1975) and Davis et al. (1975) both reported an increase in percent cookloss with mechanical tenderization. This was not the case in this study. However, the products in this study were restructured products containing sodium tripolyphosphate rather than solid-muscle cuts containing no additives.

Table 6. Effect of Mechanical Tenderization on the Shear Value, Tensile Strength and Percent Cookloss of Restructured Pork Manufactured from Pre-Rigor Sow Meat*

Treatment	*Shear(kg)*	*Tensile strength(kg)*	*Cookloss (%)*
Tenderized	8.3[a]	.52[a]	20.4[a]
Non-Tenderized	8.9[a]	.39[b]	20.1[a]
S.E.M.	0.9	.04	0.3

[a,b]Means in the same column with different letters differ ($P<0.06$).

*Cordray, 1983.

In another part of this study, TBA values for fresh and cooked restructured pork were determined initially (Day 0) and after 30, 60 and 90 days of storage. There was a difference ($P<0.05$) in TBA value between the fresh and the cooked treatments at 30 days of storage. This difference was also observed after 60 and 90 days of storage. No effect in TBA value was observed after 30, 60 or 90 days of storage between tenderized and non-tenderized treatments. Booren et al. (1981) reported higher TBA values for restructured beef steak (0.0% salt) manufactured with mechanical tenderization than those manufactured with no tenderization. In this same study, Booren and co-workers reported no significant difference in TBA values for mechanically tenderized vs. non-tenderized restructured steaks containing 0.5% salt. Results of this study agree with the later findings reported by Booren et al. (1981). Sodium tripolyphosphate used in the formulation apparently aided in the prevention of oxidative rancidity since TBA values after 90 days of storage for the fresh product were acceptable. Cooked smokehouse yields of the four treatments averaged 92.7% with no significant differences among the treatments.

The objectives of the second study conducted by Auburn University utilizing pre-rigor sow meat were to investigate the effect of three different grind sizes and two blend ratios on the textural and sensory properties of restructured pork.

A 2 x 3 factorial arrangement of treatments was used to investigate the effect of two blend ratios and three grind sizes on the textural and sensory properties of restructured pork. This study utilized animals similar to those in the mechanical tenderization study. The carcasses were boned and the lean/fat muscle mass was tenderized in the same way as in the previous study. After mechanical tenderization, the lean/fat muscle mass was separated into a trimming and lean chunk component. The trimming component was ground through a 3.18 mm plate and the lean muscle component was ground through a three hole kidney plate. After grinding once through the kidney plate, the lean muscle component was blended for 1 minute in a paddle mixer and separated into three parts, one of which was used without further treatment. The second part was reground through the kidney plate and the third part was reground through a 10.0 mm plate. The two components of the manufacturing meat block were blended together for 15 minutes either in a ratio of 60% lean chunks/40% fine ground or 50% lean chunks/50% fine ground. At the start of the blending cycle, salt (1%), sodium tripolyphosphate (0.25%), acid neutralized liquid smoke (1.5%), water (4.5%) and seasoning (0.9%) were added. After blending, the meat was stuffed into 90 mm fibrous casings and frozen.

There were no differences ($P<0.05$) in percentage cookloss between the two blend ratios or three grind sizes. This is in contrast to reports of Popenhagen and Mandigo (1978) and Chesney et al. (1978). A possible explanation for the uniform cookloss observed is that the products contained sodium tripolyphosphate which aids in decreasing cookloss.

Panelists detected no significant difference in cohesiveness between the two blend ratios. However, they did rate the kidney plate treatments and the kidney plate × kidney plate treatments as more cohesive than the kidney plate × 10 mm plate treatments. There was not a significant difference in connective tissue between the two blend ratios. However, all three of the grind sizes were different ($P<0.05$) from each

Table 7. Effect of Grind Size and Blend Ratio on Connective Tissue in Restructured Pork Manufactured from Pre-Rigor Sow Meat*

	Grind Size			
Blend Ratio	*Kidney Plate*	*Kidney plate x Kidney Plate*	*Kidney plate x 10 mm plate*	*$\bar{X}$*
60% chunks/ 40% fine ground	5.33[1]	5.92	6.72	5.99[a]
50% chunks/ 50% fine ground	5.49	6.12	6.70	6.10[a]
$\bar{X}$	5.41[a]	6.02[b]	6.71[c]	

[a,b,c]Means in the same row or column with different letters differ (P<0.05).
[1]$LSD_{(.05)}$ for two-way means = .48.
*Cordray, 1983.

other (Table 7). The larger grind sizes probably allowed some pieces of tough connective tissue found in sow carcasses to be included in the final product. Panelists detected no significant differences among treatments for juiciness or flavor. There was a difference (P<0.05) in shear value between the two blend ratios with blends containing higher percentage of chunks having higher shear value. Also, the kidney plate and kidney plate x kidney plate treatments had significantly higher shear values than the kidney plate x 10 mm plate treatments. The trend observed in shear values was for treatments containing large chunks or a higher percentage of chunks to have a higher shear value. There were no significant differences between blend ratios or among grind sizes for tensile strength.

Results of this study indicate that a blend ratio of 50% chunks/50% fine ground is comparable to a ratio of 60% chunks/40% fine ground. There was not a difference (P<0.05) between the two blend ratios for any of the factors examined, with the exception of shear value. Results also indicate that cohesiveness and amount of detectable connective tissue decrease as particle size decreases.

In the third study conducted at Auburn University utilizing pre-rigor sow meat, encapsulated food acids were used to produce a pseudo country ham type product. Animal selection, boning, mechanical tenderization and muscle separation into a lean component and trimming component were the same as in the two previous pre-rigor sow studies. Both components were ground through a 3-hole kidney plate. The lean component was reground through a 10 mm plate and the trimming component was reground through a 3.18 mm plate. The two components of the manufacturing meat block were blended together for 12 minutes in a ratio of 50% lean chunks and 50% fine ground to produce a 39 kg master batch. At the start of the 12 minute blending cycle, the following ingredients were added: salt, sucrose, liquid smoke, water and sodium erythrobate. After 12 minutes of blending, four 9.07 kg batches were drawn from the master batch. Additional ingredients were added to each of the four 9.07 kg batches to create the four different treatments. Water (3.0%) was added to the control treatment. The sodium acid pyrophosphate treatment (SAP) received an additional 3.0% water and 0.5% sodium acid pyrophosphate. The lactic acid (LA) treatment contained 3.0% water, 0.5% sodium acid pyrophosphate, and 1.0% encapsulated lactic acid. The glucono-delta-lactone (GDL) contained 3.0% water, 0.5% sodium acid pyrophosphate and 1.0% encapsulated glucono-delta-lactone. After the additional ingredients were added to a 9.07 batch, it was blended for 2 minutes giving an overall mixing time of 14 minutes. The encapsulated food acids were added late in the blending cycle to minimize the amount of mechanical agitation the capsule was subjected to in an effort to prevent early release of the food acid due to a damaged capsule.

The blending operation was completed at approximately 90 minutes postmortem and products were then stuffed into 90 mm diameter fibrous casings, placed in a heat processing oven and cooked to an internal temperature of 67°-69°C.

Panelists detected no differences in cohesiveness, juiciness or connective tissue among the treatments. The SAP and GDL treatments were rated as having a significantly more intense flavor than the control. These flavor differences appear to be directly related to differences in pH, which agrees with the work of Brown (1981) who reported that as the pH of a product decreases, the flavor becomes more intense. It is likely that an even larger difference would have been observed in flavor intensity if the LA and GDL treatments had been lower in final pH. However, this lower pH might have affected yield in an adverse manner.

Objective analysis detected no differences in shear value or tensile strength among the treatments (Table 8). Data for percent conversion of total meat pigments to cured meat pigments (nitroso-hematin) is also shown in Table 8. In the curing reaction, the more of the total meat pigment that can be converted to the cured meat pigment, the more intense and desirable will be the color in the final product. Sodium acid pyrophosphate was included in three of the treatments in this study because of its ability to speed up the curing reaction. Speed of the curing reaction is very important in products such as those produced in this study because very

Table 8. Shear Values, Tensile Strength and Nitroso — Hematin Pigment Content of Restructured Pork Manufactured from Pre-Rigor Sow Meat*

Treatment	*Shear(kg)*	*Tensile strength(kg)*	*Pigment conversion (%)*
Control	5.5[a]	0.272[a]	58.6[b]
Sodium acid pyrophosphate	6.1[a]	0.240[a]	70.1[a,b]
Lactic acid	5.7[a]	0.195[a]	71.7[a,b]
Glucono-delta-lactone	6.1[a]	0.199[a]	75.7[a]
S.E.M.	0.3	0.040	7.4

[a,b]Means in the same column with different letters differ (P<0.05).
*Cordray, 1983.

little time is allowed in the manufacturing process for the reaction to take place. The trend observed in this study was for the SAP, LA and GDL treatments to have more of the cured meat pigment in the final product than the control. No difference in percent pigment conversion was observed among the SAP, LA and GDL treatments, even though the pH of the LA and GDL treatments was lower than the pH of the control. This was probably due to the fact that by the time the encapsulated acids were released into the product, the curing reaction had already taken place and thus was not affected by an additional lowering of pH.

After mixing, the pH of the control was different ($P<0.05$) than the SAP, LA and GDL treatments. The average difference of .44 pH units was due to the addition of sodium acid pyrophosphate during the mixing cycle.

After cooking, three different levels of pH were observed. The control had a higher ($P<0.05$) pH than the SAP treatment and the SAP treatment had a higher ($P<0.05$) pH than the LA and GDL treatments. Differences in pH observed at this time among the SAP, LA and GDL treatments were due to the release of the encapsulated acids during the cooking cycle. The encapsulated lactic acid lowered the pH of the LA treatment by .52 pH units while the encapsulated glucono-delta-lactone lowered the pH of the GDL treatment by .64 pH units.

During chilling, the pHs increased by an average of .14 due to the natural buffering capabilities of the meat. The final pH, taken after the product had chilled, ranked in the same order as those taken after cooking with the control having the highest pH and the GDL treatment having the lowest pH.

In both cooked yield and chilled yield, the control had the highest yield with the other three treatments having slightly lower yields. However, there was not a significant difference ($P<0.05$) in yield among the four treatments.

The trend was for the lower pH products to have slightly less water-holding capacity than the control. However, the differences observed were not significant. Normally, greater differences in water holding capacity might be expected than observed in this study. However, it is believed that by the time the pH of the low pH products approached the iso-electric point of meat, during the cooking cycle when the food acids were released, some of the protein had already begun to coagulate, thus trapping moisture within the tissue with the net result being an increase in bound water.

The results of this study indicate that encapsulated food acids can be used with pre-rigor meat to produce products with a more intense flavor and more desirable color than would be possible without the encapsulated acid. These advantages are accomplished without deleterious effects on the chemical, physical or sensory characteristics of the product.

Summary

In the future, it appears that we are going to see considerable interest in pre-rigor processing of meat. Certainly there are going to be some logistical problems to overcome when the commercial industry widely adopts hot processing technology. In hot processing, once the animal is exsanguinated, there must be continuous flow until the carcass is processed into finished products. This can be difficult to coordinate, particularly when various parts of the carcass are going into different processing procedures. However, I feel that the economics of production are going to force us to make some if not all aspects of hot processing workable and practical.

More research is needed in the area of manufacturing of restructured meats from pre-rigor meat. Areas of importance include methods of comminution, binding, chilling, color and improving shelf life.

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