To the Graduate Council:

I am submitting herewith a thesis written by German A. Granados entitled "A Comparison of Hot and Cold Processing of Pork for Fresh, Cured and Smoked, and Emulsified Meat Products." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

M. James Riemann

M. James Riemann, Major Professor

We have read this thesis and recommend its acceptance:

D. Michael Davidson

H. Dwight Loveday

Accepted for the Council:

C. W. Minkel

The Graduate School

A COMPARISON OF HOT AND COLD PROCESSING OF PORK FOR FRESH, CURED AND SMOKED, AND EMULSIFIED MEAT PRODUCTS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

German A. Granados

June 1984

To my parents, German and Consuelo Granados, for their love and support through all my life

ACKNOWLEDGMENTS

The author wishes to express his deep gratitude to his major professor, Dr. M. James Riemann, for his kindness and patient help throughout the master's program. Gratitude is also extended to Dr. Dwight Loveday and Dr. Michael Davidson for their suggestions and help as committee members.

Thanks are expressed to Dr. J. T. Miles, Department Head, for his useful advices.

Thanks to the meat processing section, students, and staff, which collaboration made possible this research.

Thanks to the sensory evaluation section and to all who directly or indirectly contributed to this thesis.

ABSTRACT

Cured hams and bellies, vacuum packaged fresh pork loins, and emulsion type sausages (bologna) were processed using cold (conventional) and hot processing. Fresh cut yields, cooking losses (hams, bellies, sausages), pH, water holding capacity, emulsion capacity, tenderness (loin chops), purge (loin roasts), distortion (bellies), color (fresh pork loin), juiciness and flavor (bologna) were compared to determine the effect of the two treatments on these physical and sensory properties.

There were no significant differences in fresh cut yields, cooking losses, water holding capacity, emulsion capacity, tenderness, purge, color, fresh and cured belly areas, or bologna juiciness and flavor. But, hot processed carcasses had lower belly and sausage cooking losses, shear values, and purge, and higher water holding capacity, and emulsion capacity than the cold processed carcasses.

Hot processed carcasses had significantly higher pH ($P<0.05$), wider fresh and cured bellies ($P<0.01$) than cold processed carcasses.

Fresh and cured cold processed bellies were longer ($P<0.01$) than the hot processed carcasses.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

CHAPTER I

INTRODUCTION

There has been substantial research in prerigor or hot processing of pork since the classical work of Mandigo and Henrickson (1966). Cured pork products (ham, loin, and bacon), sausage products (fresh pork sausage, and emulsion sausage), fresh carcass cuts, and restructured fresh meat cuts, have been technically and economically evaluated to determine the industrial applications of this process.

As the name implies, hot processing consists of processing the animal a short time after its death, and before the onset of rigor mortis. During this prerigor period, the meat has a very high pH, and presents many physical and sensory characteristics that are notably diminished when the rigor mortis approach. Lawrie (1980) stated that the potential technical advantages of hot processing meats were: greater meat yield, less drip in vacuum pack, less unsightly staining of fat, more uniform color, opportunity to mold meat, and greater water-holding capacity.

With regard to the potential economic advantages of hot processing, Mandigo (1966, 1977) found: less processing time, lower fabrication costs, faster inventory turnover, less cooler space, less cutting and chilling losses, less heat energy (42.7%), and less refrigeration energy (39.5%). Noble (1977) observed a 31.9% reduction in energy required to refrigerate hot cut beef compared to beef cut by the conventional process.

Among the potential disadvantages of hot processing are: greater hygiene and temperature control are required to minimize microbiological spoilage; desirability of boning on the rail; less easy to cut, trim and vacuum pack; unconventional shapes of cuts; difficulty in synchronizing slaughter, boning and manufacturing lines; and difficulty in introducing into conventional plants (Lawrie, 1980).

Because most of the research in the hot processing area has been done working with one specific cut, it seemed very feasible that the use of a whole hot processing scheme of production could lead to obtaining good quality products at a low production cost. The objectives of this research were to investigate the effect of hot processing on the quality and yield of cured ham and belly, vacuum packaging fresh loin roasts, and emulsion type sausages in an integrated hot processing system.

CHAPTER II

REVIEW OF LITERATURE

1. CURED HAMS AND BELLIES

Cured hams and bellies are traditionally manufactured using cold deboning of pork. In the conventional processing pattern (Mandigo, 1966) the animal is slaughtered, and cut into two sides which are immediately refrigerated to decrease microbial growth. Because of its body temperature (around 37°C during slaughter), chemical composition (high protein and mineral content), and the presence of external (workers, equipment, air, water) and internal (viscera, blood) sources of contamination, pork constitutes a very good media for spoilage microorganisms.

After chilling, which usually takes 24 hours at 0-5°C, the desired cuts are removed from the carcass, and brine is usually pumped into those cuts to start the curing process. Two to four days are ordinarily necessary to reach a good cure distribution at refrigeration temperatures. The cured cut is then cooked, smoked, chilled, refrigerated, and packed in order to be ready for distribution.

In hot processing of pork, the initial chilling step is eliminated and the carcass goes directly from slaughter to the cutting area for separation of the different cuts from the carcass. The animal must be processed within a few hours to minimize microbial growth (Lawrie, 1980).

The hot cuts are then pumped with brine to the desired cure level, cooked and smoked, chilled, refrigerated, and packed for marketing (Mandigo, 1966). Because the cut is hot, less energy is required for these processes.

2. FRESH PORK LOINS

During conventional processing of fresh pork loins, the loins are removed from the chilled carcass, the chops or roasts from the loin vacuum packaged (the bone can be removed before this step), and the product chilled for distribution (Moore, 1966; Mandigo, 1966).

Hot processing differs from cold or conventional processing in that the loin is removed immediately after the animal is slaughtered. The remaining steps are identical to the conventional process.

3. EMULSION TYPE SAUSAGES

In conventional processing of emulsion type sausages the chilled cuts and trimmings are ground and mixed, then the curing ingredients are added. The mixture is then emulsified, stuffed, cooked, smoked, chilled, refrigerated and packed for distribution (Stilwell and Mandigo, 1978).

Production of emulsion type sausages with hot processed meat differs from the traditional process by the use of hot boned cuts and trimmings which are ground and mixed at a very high temperature (37-40°C) which makes it necessary to add ice or cold water to avoid protein denaturation (Acton, 1969). The mixture is further processed according to the above mentioned scheme.

4. YIELD

Mandigo (1966, 1977) and Davidson (1968) did not find significant differences in final ham weight between the hot processed and the conventional processed ham.

Using sodium tripolyphosphate at 3.3% in the pickle, Krause (1978) found a significant improvement ($P<.05$) in external color, sliceability, taste, and yield of cured hams independent of tumbling effect. Wierbicki (1976) showed that as little as .3% of phosphate in the finished product was necessary for an increase of 5% in product yield (phosphates improve the water holding capacity of the ham).

Mandigo (1977) showed that there was no difference in the yield of bacon or length of the formed slabs prior to slicing between hot processed and traditionally processed bacon.

5. COOKING FACTORS

Hot processed hams had significantly lower drip and cooking losses than cold processed hams (Weiner et al., 1964). No differences in juiciness (Mandigo, 1966) or ham shrink losses (Davidson, 1968) were reported. Hoes et al. (1980) concluded that hot processing did not affect any of the main cooking factors.

Hoes (1980) determined that phosphate injection did not affect ($P<.05$) overall acceptability or cooking losses of loin chops, but flavor desirability declined with storage time. He also found that injection of loins to 110% of their weight with a 5% solution of sodium hexametaphosphate and sodium pyrophosphate produced juicier, more tender, heavier chops; however, the chops had more thaw loss, less browning during cooking, and less desirable flavor than loin chops of conventionally processed loins ($P<.05$).

The research of Stilwell et al. (1978) found no differences for severe and normal cookout of finished frankfurters, the differences in emulsion stability values were also not significant for total ml of loss per 100 grams of emulsion; the accelerated processed frankfurter had greater ($P<.01$) gel/water loss than the conventional ones; the accelerated processed pork resulted in less fat loss ($P<.05$).

6. TENDERNESS

Weiner (1964) found cured hams that had been hot processed were more tender than the conventionally processed hams. In contrast, Mandigo (1966) determined that while hot processed hams were significantly more tender according to a taste panel ($P<.01$), no significant differences existed in shear values between these two types. Hoes et al. (1980) determined that the primary main disadvantage of hot processing, the possibility of reduced tenderness, could be overcome by the injection of a phosphate solution one hour postmortem. However, decreased flavor desirability offset the improvement in tenderness and juiciness. Hoes theorized that this adverse effect on flavor could be eliminated using flavorings or reduced phosphate levels.

Theno (1977) found that the mechanical treatments of boneless hams, known as tumbling and massaging, improved the uniformity of tenderness and water binding capacity of the finished products. Prerigor salting and massaging also showed a stronger tenderizing effect than that caused by prerigor salt infusion alone. The improved tenderness characteristics were detected both by shear tests and a taste panel (Judge, 1979).

No significant differences in fresh pork loin thaw loss, moisture loss, or shear values were reported by Moore et al. (1966). Marsh (1972) found cold shortening increased toughness 24% in fresh pork loins that were rapidly cooled at 0°C after excision, compared with 200-400% in beef. Marsh (1972) also reported that pork longissimus muscle, cooked to an internal temperature of 80°C, had significantly higher ($P<0.01$) shear values (13.07 kg/2.54 cm core) when hot processed compared to cold processed muscle (9.65 kg/2.54 cm core).

Precooking of hot processed chops, to improve tenderness, was considered infeasible by Montgomery et al. (1977) due to decreased tenderness related to muscle contraction; however, pre-cooking of hot processed roasts by conventional roasting appeared feasible because of lower cooking losses and acceptable tenderness.

The workers concluded that microwave precooking of chops and roasts was less desirable than conventional precooking because of increased cooking losses and decreased tenderness.

7. COLOR

When compared with the traditional process, hot processing improved the uniformity of the cured color of hams (Mullins, 1957) and the use of polyethylene bags accompanied with submerging for 30 minutes in a cold brine produced a notable color improvement (Wisner-Pedersen, 1961).

Mandigo (1967, 1973) found a higher, but not significant, nitroso and total pigment content in hot processed hams. Kastner (1977) showed that pork color was improved when the curing salts are introduced prerigor rather than postrigor.

Hot processed bacon was found to have greater pigment conversion and greater residual NaCl concentration ($P<.05$) than the control (Amundson, 1981). The study also showed that nitrosamine levels were not influenced by belly handling variables.

8. EMULSION PROPERTIES

Nelson (1967) found that extractable protein at 30 minutes post-mortem was 65% decreasing to a minimum of 31% at 24 hrs. and reaching 66% at 11 days of aging. Also, the extractable actomyosin was very high at 30 minutes post-mortem (27%), minimum at 4 days (2%), and increased during aging (35% at 11 days).

Stilwell (1978) found that the accelerated processed pork emulsion percent solids was higher ($P<.01$) than the cold processed pork; no significant difference was obtained for emulsification capacity of the lean pork tissue that had undergone accelerated or conventional processing prior to use in frankfurter production; finally water holding capacity results indicated superior ($P<.05$) water holding capacity for the conventional processing method. The study concluded as very feasible of using accelerated hot processing in frankfurter manufacture.

Poulanne (1983) found that firmness of sausages increased ($P<.05$) when sodium tripolyphosphate or preblends with 4% salts were used. He also concluded that current salt levels could be reduced without detrimentally affecting physical, chemical or sensory properties of emulsion sausages.

Judge (1980) showed that NaCl had prooxidative effect in pre-rigor and postrigor ground pork, but that prerigor samples were much less susceptible to lipid oxidation after grinding and salting. The partial inhibition of the prooxidant effect of NaCl observed with ground and salted prerigor pork was suggested to be the result of an induced high ultimate pH which decreased the oxidative effect of non heme iron (Wills, 1966).

CHAPTER III

MATERIALS AND METHODS

1. EXPERIMENTAL DESIGN

A total of 12 hogs were obtained from the Knoxville Agricultural Experiment Station of the University of Tennessee. Six hogs ranging in weight of 109 to 131.8 kg were used in each of two replications. The hogs were slaughtered and processed at the University of Tennessee Meat Laboratory. The right side of each hog was conventionally or cold processed as postrigor muscle, and the left side was processed as prerigor or hot processed.

2. CURED CUT PROCESSING AND EVALUATION

Hams were processed by pumping to 10% with a brine made of ingredients shown in Table 1. The hams were held in a cover pickle (same ingredients) five days then cooked and smoked in an Alkar oven to an internal temperature of 65.5°C. Bellies were held in a cover pickle (ingredients shown in Table 2) four days then cooked and smoked in an Alkar oven to 53.9°C internal temperature (Figure 1). Conventional and hot processed hams were evaluated for fresh and cured yields, and cooking losses. Bellies were evaluated for fresh and cured yields, cooking loss and distortion of the cut during processing. Distortion of the belly was determined by measuring the length of the belly on the loin and teat sides and width was

TABLE 1. Ham Curing Ingredients

Ingredient	% in Brine	Amount in Product (%)
Salt	16.60	2.50
Sugar	6.60	1.00
NaTPP	3.30	0.50
$NaNO_2$	0.10	150 ppm

TABLE 2. Belly Curing Ingredients

Ingredient	% in Brine	Amount in Product (%)
Salt	10.00	2.00
Sugar	3.00	0.60
NaTPP	2.50	0.50
$NaNO_2$	0.05	100 ppm

<u>Cold Processing</u>

Slaughtering

↓

Chilling
(24 hours at 0-5°C)

↓

Cutting

↓

Curing

↓

Cooking and Smoking

↓

Chilling

<u>Hot Processing</u>

Slaughtering

↓

Cutting

↓

Curing

↓

Cooking and Smoking

↓

Chilling

FIGURE 1. Procedure for cold and hot processed hams and bellies.

measured at points 0, 20, 40, 60, 80, and 100% of the average length of the belly from the anterior end.

3. FRESH LOIN PROCESSING

Figure 2 shows the processing scheme used for the fresh pork loins. Cold and hot processed loins were evaluated for tenderness by the Warner Bratzler Shear Method using a 1.27 cm core. Purge loss was measured by collecting the purge accumulated in the bag in a graduated cylinder. Color of loin samples was measured using a Hunter Color Difference Meter (Model D-25-2) standardized with a white plate (C2-21.25) that had standard values of L = 91.03, a = -1.3 and b = 1.6.

4. EMULSION SAUSAGE PROCESSING

The shoulder of each carcass was skinned, boned and used to make an emulsion-type sausage (bologna). Prior to making the sausage, the lean from the shoulder of each side was evaluated for pH, water holding capacity (Wierbicki, 1958) and emulsion capacity (Swift, 1961; Webb, 1970). Fat content of the lean was determined by the modified Babcock Method of Smith (1982). The bologna was made according to the scheme presented in Figure 3. Table 3 shows the formulations used. Four different sodium tripolyphosphate (NaTPP) levels (0%, .17%, .33%, .50%) were tested in both the hot processing and cold processing treatments. The bologna was cooked to an internal temperature of 65.6°C, chilled, weighed to determine

<u>Cold Processing</u>

Slaughtering

↓

Chilling
(24 hr. at 0-5°C)

↓

Cutting

↓

Boning

↓

Vacuum Packaging

↓

Chilling

<u>Hot Processing</u>

Slaughtering

↓

Cutting

↓

Boning

↓

Vacuum Packaging

↓

Chilling

FIGURE 2. Procedure for cold and hot processed fresh pork loin roasts.

<u>Cold Processing</u>

Slaughtering

↓

Chilling

↓

Shoulder and Trimmings

↓

Grinding and Mixing

↓

Curing
0%, 0.17%, 0.33%, 0.50%
NaTPP

↓

Emulsion Making

↓

Stuffing

↓

Cooking and Smoking

↓

Chilling

<u>Hot Processing</u>

Slaughtering

↓

Shoulder and Trimmings

↓

Grinding and Mixing

↓

Curing
0%, 0.17%, 0.33%, 0.50%
NaTPP

↓

Emulsion Making

↓

Stuffing

↓

Cooking and Smoking

↓

Chilling

FIGURE 3. Procedure for making bologna from cold and hot processed pork.

TABLE 3. Emulsion Sausage (Bologna) Formulations

Ingredient	Amount
Pork	3420.00g
Beef (50% fat)	1140.00g
Ice	1200.00g
Salt	136.20g
Corn Syrup	90.80g
White Pepper	23.00g
Nutmeg	4.00g
Ascorbic Acid	2.40g
$NaNO_2$	0.70g
NaTPP--Level I	0.00g
Level II	8.30g
Level III	16.70g
Level IV	25.00g

cooking loss, and samples were vacuum packaged and stored (5°C) for later evaluation of flavor and juiciness.

5. SENSORY EVALUATION

Juiciness and flavor of the bologna was evaluated by sensory analysis. The criteria for evaluation were listed on the score sheet, a copy of which is presented in the Appendix. Forty-two panelists participated in the hedonic evaluation of the bologna samples containing different levels of NaTPP. Each panelist received six samples, each 1 cm thick. The samples were coded with three-digit random numbers, and the NaTPP level and presentation order were randomized.

6. ANALYSIS OF DATA

All data were analyzed by analysis of variance (Steel, 1960).

CHAPTER IV

RESULTS AND DISCUSSION

1. FRESH CUT YIELDS

The mean and F-ratios of analysis of variance for the effect of hot and cold processing on fresh cut yields are presented in Table 4. There were no significant differences because of the type of processing for any of the wholesale cuts. These results agree with Mandigo (1966, 1977, 1979).

2. COOKING LOSSES

The means and F-ratios of analysis of variance for the effect of hot and cold processing on hams, bellies, and emulsion type sausage cooking losses are presented in Table 5.

There were no significant differences in ham or belly cooking losses, which agree with Mandigo (1977). However, Weiner (1966) found lower cooking losses in the hot processed hams ($P<0.05$).

The emulsion sausage cooking losses were lower in the hot processing treatment but were not significant ($P>0.05$).

3. pH

The analysis of variance for the pH of hot and cold processed pork is presented in Table 6. Meat from the hot processed carcasses had a higher ($P<0.05$) pH than the meat from the cold processed

TABLE 4. Means and F-Ratios of Analysis of Variance for Effect of Hot and Cold Processing in Fresh Cut Yields

	Weights (kg)		
Cuts	Hot Processing	Cold Processing	F-Ratios
Untrimmed Hams	10.91	10.47	1.30^{ns}
Trimmed Hams	9.99	9.77	0.38^{ns}
Untrimmed Loins	10.19	10.41	0.02^{ns}
Trimmed Loins	7.75	7.83	0.05^{ns}
Bellies	5.87	6.07	0.19^{ns}
Untrimmed Shoulders	10.81	10.74	0.01^{ns}
Trimmed Shoulders	8.86	8.38	0.97^{ns}

^{ns}Not significant at $P<0.05$.

TABLE 5. Means and F-Ratios of Analysis of Variance for Effect of Hot and Cold Processing in Cooking Losses in Cured Hams and Bellies and Emulsion Sausages

Product	Cooking Loss (%) Hot Processing	Cooking Loss (%) Cold Processing	F-Ratios
Cured Hams	15.12	14.58	0.36^{ns}
Cured Bellies	10.37	11.33	0.75^{ns}
Emulsion Sausages	6.27	7.64	1.07^{ns}

^{ns}Not significant at P<0.05.

TABLE 6. Analysis of Variance for the pH of Hot and Cold Processed Pork

Source	SS	df	MS	F
Treatment	0.25	1	0.25	4.17*
Error	1.25	22	0.06	
Total		23		

*Significant at P<0.05.

carcasses (6.04 and 5.84, respectively). The mean pH of hot processed carcasses was lower than expected because of the low pH (5.68 and 5.55) of 2 of the 12 carcasses. The pH for the two processes are presented in Table 7.

4. WATER HOLDING CAPACITY

The analysis of variance for the water holding capacity ratio (free water area/meat area) of the ground shoulder is presented in Table 8. A lower water holding capacity ratio indicates a greater ability of muscle to bind water. The hot processed pork had a lower ration, 1.36 compared to 1.60, than the cold processed pork, but the difference was not significant ($P<0.05$). Stilwell (1978) found higher water holding capacity for the cold processed hogs ($P<0.05$), which did not agree with these results. The water holding capacity ratio decreased with the pH ($r = -.42$).

5. EMULSION CAPACITY

The analysis of variance for the emulsion capacity of the ground shoulder is presented in Table 9. Emulsion capacity of the hot processed pork was 89.69 ml oil/gm of meat compared to 85.79 ml oil/gm of meat for the cold processed meat. There was no significant difference in emulsion capacity between hot and cold processed pork. These results agree with Stilwell (1978).

TABLE 7. pH of Cold and Hot Processed Pork

Carcass No.	Hot Processing	Cold Processing
1	5.68	5.68
2	5.55	5.53
3	6.30	6.10
4	5.90	6.23
5	5.95	5.88
6	6.38	5.75
7	6.10	5.68
8	6.30	5.80
9	6.13	6.10
10	6.03	5.80
11	6.20	5.83
12	5.98	5.70
Mean	6.04	5.84

TABLE 8. Analysis of Variance for the Water Holding Capacity Ratio of Ground Shoulder of Hot and Cold Processed Pork Carcasses

Source	SS	df	MS	F
Treatment	0.34	1	0.34	1.90[ns]
Error	3.85	22	0.18	
Total		23		

[ns]Not significant at $P<0.05$.

TABLE 9. Analysis of Variance for Emulsion Capacity of Ground Shoulder of Hot and Cold Processed Pork Carcasses

Source	SS	df	MS	F
Treatment	91.06	1	91.06	1.39[ns]
Error	1437.12	22	65.32	
Total		23		

[ns]Not significant at $P<0.05$.

6. TENDERNESS

The analysis of variance for tenderness of fresh loin chops using the Warner-Bratzler Shear is presented in Table 10. Loin chops from the hot processing treatment had a slightly lower mean shear force value (2.13 kg) than the loin chops of the cold processing treatment (2.24 kg) but the differences were not significant ($P<0.05$). These results agree with Moore (1966), but Marsh (1972) found greater tenderness in the cold processed pork loins due to the cold shortening effect in the hot processed loins.

7. PURGE LOSS

The analysis of variance for the vacuum packaged fresh loin roast purge loss is presented in Table 11. The hot processed loin roasts had lower purge loss (4.18 ml/kg of meat) than the cold processed roasts (7.49 ml/kg of meat) but the difference was not significant ($P<.05$). The purge increased in loins from carcasses which had a rapid pH drop ($r = -0.52$).

8. COLOR

The names and F-ratios of analysis of variance for the fresh loin muscle color using the Hunter Color Difference Meter (Model D-25-2) are presented in Table 12. No significant differences in any of the L (visual lightness), a (+ = redness, 0 = gray, - = greeness), or b (+ = yellow, 0 = gray, - = blueness) values

TABLE 10. Analysis of Variance for Warner Bratzler Shear Tenderness Measurements of Hot and Cold Processed Loin Chops

Source	SS	df	MS	F
Treatment	0.08	1	0.08	0.38^{ns}
Error	4.69	22	0.21	
Total		23		

^{ns}Not significant at P<0.05.

TABLE 11. Analysis of Variance for Purge Loss of Vacuum Packaged Fresh Loin Roasts from Hot and Cold Processed Pork Carcasses

Source	SS	df	MS	F
Treatment	65.67	1	65.67	2.16^{ns}
Error	668.86	22	30.40	
Total		23		

^{ns}Not significant at P<0.05.

TABLE 12. Means and F-Ratios of Analysis of Variance for Color of Vacuum Packaged Pork Loins from Hot and Cold Processed Pork Carcasses

Color Component[1]	Hot Processing Mean	Cold Processing Mean	F-Ratios
L	47.11	48.27	0.59^{ns}
a	8.68	8.90	0.23^{ns}
b	9.05	9.39	0.45^{ns}

[1]Color was measured using a Hunter Color Difference Meter.

^{ns}Not significant at $P<0.05$.

were found. However, the cold processed had higher L, a, and b values which may be related to a lower pH.

9. BELLY DISTORTION MEASUREMENTS

The means and F-ratios of the analysis of variance for belly distortion measurements are presented in Table 13. The cold processed fresh bellies were longer ($P<0.01$) than the hot processed bellies but the hot processed fresh bellies were wider ($P<0.01$) than the cold processed bellies. Therefore, no significant differences were found in total area of the fresh bellies.

Although the cold processed cured bellies were longer than the hot processed cured bellies, there was no significant difference between the two treatments. Mandigo (1977) found that cold processed bellies were significantly longer ($P<0.01$).

TABLE 13. Means and F-Ratios of Analysis of Variance for Belly Distortion Measurements

Measurements	Hot Processing Mean	Cold Processing Mean	F-Ratios
Fresh Belly Length (cm)	49.88	59.08	14.68**
Fresh Belly Width (cm)	27.51	22.35	42.13**
Fresh Belly Area (cm)	1345.81	1321.51	0.43^{ns}
Cured Belly Length (cm)	49.64	54.43	0.53^{ns}
Cured Belly Width (cm)	22.99	20.68	11.02**
Cured Belly Area (cm)	1143.96	1130.15	0.03^{ns}

**Significant at P<0.01.

^{ns}Not significant at P<0.05.

The hot processed cured bellies were significantly wider (P<0.01) than the cold cured bellies. In contrast, Mandigo (1977) did not find a significant difference between the treatments, but there was no significant difference in cured belly area between the treatments.

10. EMULSION SAUSAGE JUICINESS

The means and F-ratios of the analysis of variance of taste panel juiciness for emulsion sausages (bologna) are presented in Table 14. There were no significant differences in juiciness at any level of NaTPP between the hot and cold processed sausages.

TABLE 14. Means and F-Ratios of Analysis of Variance for Taste Panel Juiciness Scores for Bologna by Phosphate Level

NaTPP Level	Hot Processing	Cold Processing	F-Ratios
0.00%	4.43	4.83	2.03^{ns}
0.17%	4.80	4.87	0.04^{ns}
0.33%	4.90	4.70	0.55^{ns}
0.50%	4.80	4.87	0.05^{ns}

[1]Scale: 1 = very dry, 3 = slightly dry, 5 = slightly juicy, 7 = very juicy.

[ns]Not significant at the 0.05 level.

11. EMULSION SAUSAGE FLAVOR

The mean and F-ratios of the analysis of variance of taste panel flavor scores for emulsion sausages (bologna) are presented in Table 15. There were no significant differences in flavor at any level of NaTPP between the hot and cold processed sausages.

TABLE 15. Means and F-Ratios of Analysis of Variance for Taste Panel Flavor Scores for Bologna by Phosphate Level

NaTPP Level	Hot Processing	Cold Processing	F-Ratios
0.00%	4.50	4.77	0.58[ns]
0.17%	4.77	4.43	0.94[ns]
0.33%	4.90	4.80	0.09[ns]
0.50%	4.83	4.83	0.00[ns]

[1]Scale: 1 = dislike very much, 3 = dislike slightly, 5 - like slightly, 7 = like very much.

[ns]Not significant at $P<0.05$.

CHAPTER V

CONCLUSIONS

Based on this research and the field literature data it is possible to summarize the comparisons between hot and cold processing into three general categories: physical properties of the meat, economic implications, and production related changes.

First, hot processing compares well with cold processing in most of the pork physical properties. Although not statistically significant, hot processed sides had slightly higher fresh and cured cut yields, higher emulsifying capacity and water holding capacity, lower loin purge, and lower belly and sausage cooking losses. It also appears that the cold shortening effect is not as critical in pork tenderness as it is in beef tenderness; there was no significant difference between the two treatments.

Hot processing represents, in the long run, a less expensive process than cold processing. There are substantial energy savings, less requirements in refrigeration space, less labor, faster inventory turnover, and less production cost. All these facts increase the value of hot processing as a production alternative.

Finally, in order to implement hot processing in a conventional plant the first evaluation that has to be made is if the potential economic savings justify the required investment in new facilities (cooling system remodeling), and special packaging (to speed the heat removing process), to solve the problem associated with hot meat grading, which is one of the most criticized points surrounding hot processing industrial implementation, and to maintain the whole process under good sanitary practices to avoid microbiological problems.

REFERENCES

REFERENCES

Acton, J. C. and Saffle, R. L. 1969. Preblended and prerigor meat in sausage emulsions. Food Technol. 23(3):93.

Amundson, C. M., Sebranek, J. G., Kraft, A. A., Rust, R. E., Wagner, M. K. and Robach, M. C. 1981. Effect of belly handling (chilled, frozen, prerigor) and smoking delay on regular and sorbate-cured bacon. J. Food Sci. 47:222.

Bratzler, L. J. and Smith, H. D. 1963. A comparison of the press method with taste-panel and shear measurements of tenderness in beef and lamb muscles. J. Food Sci. 28:99.

Davidson, W. D., Cliplef, R. L., Meade, R. J. and Hanson, L. E. 1968. Post-mortem processing treatments on selected characteristics of ham and fresh pork sausage. Food Technol. 22(6):114.

Gould, W. A. 1977. "Food Quality Assurance," The AVI Publishing Company, Inc., Westport, Connecticut.

Hoes, T. L., Ramsey, C. B., Hines, R. C. and Tatum, J. D. 1980. Yield and palatability of hot-processed, phosphate-injected pork. J. Food Sci. 45:773.

Judge, M. D. and Cioch, J. J. 1979. Palatability of prerigor and mechanically processed nitrite-free hams. J. Food Sci. 44:1775.

Judge, M. D. and Aberle, E. D. 1980. Effect of prerigor processing on the oxidative rancidity of ground light and dark porcine muscles. J. Food Sci. 45:1736.

Kastner, C. L. 1977. Hot processing: Update on potential energy and related economics. Proc. Meat Ind. Research Conf., Am. Meat Sci. Assoc. and Am. Meat Inst. Foundation, Chicago, p. 43.

Koniecko, E. S. 1979. "Handbook for Meat Chemists," Avery Publishing Group Inc., Wayne, New Jersey.

Krause, R. J., Ockerman, H. W., Krol, B., Moerman, P. C. and Plimpton, R. F., Jr. 1978. Influence of tumbling, tumbling time, trim and sodium tripolyphosphate on quality and yield of cured hams. J. Food Sci. 43:853.

Lawrie, R. A. 1980. "Developments in Meat Science," Pergamon Press. Oxford. Great Britain.

Mandigo, R. W. and Henrickson, R. L. 1966. Influence of hot-processing pork carcasses on cured ham. Food Technol. 20(4):186.

Mandigo, R. W. 1967. Proc. of the 20th Annual Reciprocal Meat Conference. 20:270.

Mandigo, R. W. and Kuner, G. F. 1973. Accelerated pork processing: Cured color stability of hams. J. Food Sci. 38:1078.

Mandigo, R. W., Thompson, T. L. and Weiss, G. M. 1977. Commercial accelerated pork processing: Yields of cured ham, bacon and loins. J. Food Sci. 42:898.

Mandigo, R. W., Thompson, T. L. and Weiss, G. M. 1979. Commercial accelerated pork processing: Yields of fresh carcass cuts. J. Food Sci. 44:138.

Marsh, B. B., Cassens, R. G., Kauffman, R. G. and Briskey, E. J. 1972. Hot boning and pork tenderness. J. Food Sci. 37:179.

Montgomery, T. H., Ramsey, C. B. and Lee, R. W. 1977. Microwave and conventional precooking of hot and cold processed pork loins. J. Food Sci. 42:310.

Moore, R. E., Mandigo, R. W. and Henrickson, R. L. 1966. The effect of cutting, chilling, and cooking method on the quality of pork loin. Food Technol. 20(7):107.

Mullins, A. M., Kelly, G. G. and Brady, P. E. 1958. The effect of various additives on the stability of cured ham. Food Technol. 12(5):217.

Nelson, E. 1967. Postmortem changes in protein extractability in beef, pork, and chicken muscle. J. Food Sci. 32:208.

Noble, R. and Henrickson, R. L. 1977. Yield, space, cooling energy and value of the hot muscle boned bovine carcass. Proc. Recip. Meat Conf. 30:148.

Poulanne, E. J. and Terrel, R. N. 1983. Effects of rigor-state, levels of salt and sodium tripolyphosphate on physical, chemical and sensory properties of frankfurter-type sausages. J. Food Sci. 48:1036.

Ramsbotton, J. M., Strandine, E. J. and Koonz, C. H. 1945. Comparative tenderness of representative beef muscles. Food Research. 10:497.

Smith, G. C., King, G. T. and Carpenter, Z. L. 1982. "Laboratory Manual for Meat Science," 2nd ed. American Press. Boston.

Steel, R. G. and Torrie, J. H. 1960. "Principles and Procedures of Statistics," McGraw-Hill Book Company, Inc. New York

Stilwell, D. E., Mandigo, R. W., Weiss, G. M. and Campbell, J. F. 1978. Accelerated pork processing: Frankfurter emulsion properties. J. Food Sci. 43:1646.

Swift, C. E., Lockett, C. and Foyar, A. J. 1961. Comminuted meat emulsion-The capacity of meat for emulsifying fat. Food Tech. 15(11): 468

Theno, D. M., Siegel, D. G. and Schmidt, G. R. 1977. Meat massaging techniques. Proc. Meat Ind. Research Conf., Am. Meat Sci. Assoc. and Am. Meat Inst. Foundation, Chicago. p. 53.

Warner, K. F. 1928. Progress report of the mechanical test for tenderness of meat. Proc. American Society of Animal Production. 21:114.

Weiner, P. D., Kropf, D. H., Mackintosh, D. L. and Koch, B. A. 1964. The effect of processing pork carcasses prior to rigor mortis upon muscle and fat quality. Kansas Agr. Expt. Sta. Bull. 473.

Wierbicki, E. and Deatherage, F. E. 1958. Determination of water-holding capacity of fresh meats. Journal Agriculture and Food Chemistry. 6:387.

Wierbicki, E., Howker, J. J. and Shults, G. W. 1976. Effect of salt, phosphates, and other curing ingredients on shrinkage of lean pork meat and the quality of smoked processed ham. J. Food Sci. 41:5.

Wills, E. D. 1966. Mechanism of lipid peroxide formation in animal tissues. Biochem. J. 99:667.

Wismer-Pedersen, J. and Briskey, E. J. 1961. Relationship of post-mortem acidity and temperature. Food Technol. 15(5):232.

APPENDIX

SCORE CARD FOR EVALUATING THE FLAVOR AND JUICINESS OF BOLOGNA

Judge ______________________ Date __________

Sample No.	Flavor	Juciness

Flavor

7. Like very much
6. Like moderately
5. Like slightly
4. Neither like nor dislike
3. Dislike slightly
2. Dislike moderately
1. Dislike very much

Juiciness

7. Very juicy
6. Moderately juicy
5. Slightly juicy
4. Acceptable
3. Slightly dry
2. Moderately dry
1. Very dry

Figure A-1. Score Card for Bologna Sensory Evaluation.

VITA

German A. Granados was born in Managua, Nicaragua. He attended elementary and high school in Managua, Nicaragua, and graduated in 1969. He received the Bachelor of Science degree in Biochemical Engineering in 1974 from the ITESM, Monterrey, Mexico. From 1975 to 1977 he worked in meat and dairy products processing in Managua, Nicaragua. From 1978 to 1982 he worked as a general consultant in food technology and science for the Ministry of Industry, Nicaragua. From 1979 to 1982 he taught at the Central American University, Managua, Nicaragua. In November 1982 he was accepted as a graduate student at The University of Tennessee, Knoxville. In June 1984, requirements for the Master of Science degree with a major in Food Technology and Science were completed.