EFFECTS OF SALT TYPE, LEVEL, AND SEASONINIG INTERVAL ON ION PENETRATION OF RAW AND BROILED BEEF STRIP LOINS

By

HECTOR ANGEL FLORES

Bachelor of Science
Kansas State University
Manhattan, Kansas
1983

Master of Science
Kansas State University
Manhattan, Kansas
1985

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the degree of
DOCTOR OF PHILOSOPHY
July, 1989

EFFECTS OF SALT TYPE, LEVEL, AND SEASONING INTERVAL ON ION PENETRATION OF RAW AND BROILED BEEF STRIP LOINS

Thesis Approved:

H Glen Dobbs
Thesis Adviser

Stanley E. Bullard

George V. Odell

P. L. Claypool

Robert Totusek

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to Dr. H. Glen Dolezal, my thesis advisor, for his guidance, counseling, and friendship throuhout my educational and research program. The author wishes to thank the members of his advisory committee, Dr. Stanley Gilliland, Dr. George Odell, Dr. Larry Claypool, and Dr. John J. Guenther, for their support, suggestions, and encouragement given during my studies toward the degree of Doctor of Philosophy in Food Science.

Very special gratitute is extended to Kris Novotny for her assistance, suggestions, friendship, and patience during the laboratory analysis.

Thanks are also extended to the graduate students and staff of the Animal Science Department for their friendship and support. Special thanks go to Betty Rothermel, Freddie Gant, Gina Campbell, Yang Choi, Rebecca Piston, and Robin Dodge for their help and friendship throughout my graduate studies.

To my parents, Mr. and Mrs. Hector E. Flores, I want to express my appreciation for their love and encouragement during my graduate program. Above all, my deepest

appreciation and love goes to my wife Jean for her support, understanding, and help during these times.

TABLE OF CONTENTS

LIST OF TABLES

NOMENCLATURE

Aw	Water activity
C	Degree Centigrade
Ca	Calcium ion
$CaCl_2$	Calcium chloride
Cl	Chloride ion
ECFV	Extracellular fluid volume
g	Grams
IMPS	Institutional Meat Purchase Specifications
IS	Ionic strength
K	Potassium ion
KCl	Potassium chloride
KPH	Kidney, pelvic, and heart fat
Lite salt	Commercial salt; with 40 to 50% less sodium
mg	Milligrams
$MgCl_2$	Magnesium chloride
Na	Sodium ion
NaCl	Sodium chloride or table salt
WHC	Water holding capacity

CHAPTER I

GENERAL INTRODUCTION

Sodium chloride, (NaCl), most frequently encountered in the food supply as table salt, has been labelled a villain in the American diet by some, along with fats, cholesterol, and sugar. Moreover, sodium consumption in Western diets has become a major issue in the food industry, due to its perceived relationship with hypertension and cardiovascular diseases. Sodium is an essential nutrient that is not stored by the body, even when consumed in high amounts; therefore, a minimum dietary intake is essential for the body to provide the proper osmotic balance with the extracellular fluid of the body.

Sodium compounds occur naturally in many foods such as meats, fish, dairy products, grains, and vegetables; however, dietary intake of sodium may range from 10 to 20 times greater than the minimum adult requirement. Sodium also plays a major role in the flavor and preservation of certain foods, but the information available is too limited

to evaluate the efficacy of partial or total replacement of NaCl and its antimicrobial activity in processed foods.

Public awareness of dietary sodium is becoming evident in consumer surveys. Consequently, low salt products are becoming more popular in the market place. Reduction of dietary sodium has been recommended as a means of decreasing the risk for hypertension and subsequent cardiovascular diseases. Concepts of either reducing salt levels or replacing part of this NaCl with other types of chloride salts have been investigated. Of these substitutes, potassium chloride (KCl) appears to be the best substitute. This study was designed to determine the effects of salt type, level and seasoning interval on the physical properties of raw and cooked beef strip loins.

CHAPTER II

REVIEW OF LITERATURE

Consumption of sodium chloride (commonly known as table salt) in the Western diet has become a major issue in the food industry, primarily because of its close relationship to human hypertension and subsequent cardiovascular disease, strokes and renal failure (Pearson and Wolzak, 1982; Sebranek et al., 1983).

Sodium compounds occur naturally in many foods such as meats, fish, dairy products, grains, and vegetables. Most processed meat products contain variable amounts of salt and have been maligned as heavy salt contributors to the diet. Table 1 lists the variability of sodium content in some processed meat products reported by USDA (Food Chem. News, 1982). This data reveals considerable variation in sodium content, even within similar product categories.

Various dietary regimens have been recommended to reduce excessive sodium intakes (AMA, 1978; USDA, 1980; and FMI, 1981). These recommendations suggest that processed meats be eliminated or severely restricted and that food

with lower sodium content be consumed. Table 2 lists some of the principal sources of sodium in an adult diet; where less than 15% of the sodium intake is from meat, fish, and poultry (Shank et al., 1982; Fregley, 1981), while grain and cereal products contributed twice as much sodium to the "total diet".

Table 1. Variability of sodium content in some processed meat products[a].

Product category	Sodium content (mg/100g)		
	Mean	Range	Ratio (high:low)
Hams	1247	654-2004	3.06
Canned luncheon meats	1294	830-1643	1.98
Pumped bacon	684	302-1249	4.14
Meat and poultry			
Bologna	1044	708-1482	2.09
Fresh pork sausage	625	140-1009	7.02

[a]Food Chem. News, 1982.

Table 2. Sodium content of the "Total Diet" and the percent contribution to total diet by commodity groups for adults in 1980[a]

Commodity group	Sodium content	
	mg/day	%
Dairy products	674	9.4
Meat, fish, and poultry	968	14.5
Grain and cereal products	1,959	29.6
Potatoes	77	1.2
Vegetables	551	8.2
Fruits	77	1.2
Sugar and adjuncts[b]	1,983	29.6

[a]from Shank et al, (1982).
[b]includes the discretionary salt added during preparation of food and at the table.

Dietary intake of sodium may range from 3900 to 4700mg (10 to 12g of NaCl) per person per day, which is 10 to 15 times greater than the minimum adult requirement (IFT, 1980) and 10 to 20 times more than necessary for physiological balance (NAS, 1980). Based on the estimated daily salt intake per person in the United States, approximately 25 to 30% is discretionary (added during home or institutional preparation or at the time of consumption). An additional 40 to 60% is added during commercial processing and is considered to be nondiscretionary (IFT, 1980). It is this nondiscretionary salt intake that is receiving the most attention by consumers, industry, and regulatory agencies.

Public awareness of sodium is becoming evident in consumer surveys. A 1982 survey by General Foods ranked sodium content of food at the highest level of consumer concern (Lovrien, 1982). Similar results were reported by the National Pork Producers Council where consumer concern for sodium was nearly twice as great in 1982 as in 1981 (Anon., 1983). Concepts for either reducing levels of salt (NaCl) added to processed meats or replacing part or all of this NaCl with other types of chloride salts have been investigated (Hand et al., 1982a; and Terrell et al., 1982). These methods generally include absolute reduction of NaCl levels and replacement of NaCl with other chloride salts containing K, Mg, or Ca. Consequently, low salt products are becoming more popular in the market place (Barbut et al., 1986b).

Studies in which sodium chloride was reduced and/or replaced demonstrated that the use of these other chloride salts had a significant effect on hydration capacities of both raw and cooked meats (Hamm, 1960). Of these substitutes, KCl appears to be the best substitute for NaCl (Terrell and Olson, 1981). Unlike NaCl, excess dietary intake of KCl has not been linked to the development of hypertension. In fact, several studies suggest that deficiencies in dietary KCl may actually cause hypertension (McCarron et al., 1984). Mixtures of sodium chloride and potassium chloride are available as replacements of table salt. Advertisements claim that 40 to 45% of the sodium can be replaced with potassium without a noticeable taste change for most consumers (IFT, 1980).

Dietary Sodium and Hypertension.

Sodium is an essential nutrient that is not stored by the body when consumed in high amounts, however, a certain minimum dietary intake is essential for the body (Sebranek et al., 1983). The physiological role of sodium is to provide the proper osmotic balance in the extracellular fluid of the body. Extracellular sodium and intracellular potassium are responsible for the cell membrane environment that is necessary for nerve impulses, muscle function, and

utilization of many metabolic components. The transport of amino acids and sugars, in many tissues for example, is regulated by sodium gradients (Gardenswartz and Schrier, 1982).

One of the most important effects of sodium, is its influence on the extracellular fluid volume (ECFV); a function that has led to the implication of sodium and hypertension (Sebranek et al., 1983). To maintain proper sodium concentrations outside the cell, physiological adjustments are accomplished by adjusting body fluid volume. Estimations by Meneely and Battarbee (1976) showed that the accumulation of 20 meg of sodium per day would increase ECFV about 1 L per week. Therefore, in a normal individual, this increased sodium accumulation will cause an increase in ECFV and eventually an increased in body weight due to water retention.

Since the Western diet is characterized by high sodium consumption, about 20% of the U.S. population which is predisposed to heavy sodium load has "essential" hypertension (Tobian, 1979), a term used to describe the 90% of cases in which the causes of hypertension is unknown. The estimated number of affected individuals in the United State approaches a total of 40 million, whereas the incidence of hypertension in some groups such as the black population may be as high as 40% (AMA, 1983).

Hypertension in an individual can not be predicted by the level of sodium consumption (Tobian, 1979). Meneely and

Battarbee (1979) reported that dietary sodium restriction reduces blood pressure in some individuals but not in others. Furthermore, only 10 to 30% of the individuals on restricted sodium diets may experience reduced blood pressure (Andres, 1982).

Salt and Salt Substitutes in Processed Meats.

For many technological and economic reasons, some NaCl is essential in processed meats (Terrell, 1982). In addition to the well known use as a seasoning agent (mostly contributed by the sodium ion), it is also critically needed for intracellular protein extraction to promote binding and texturing (Whiting and Richards, 1978). Some other examples of its benefits are: 1) it activates proteins to increase hydration, 2) it decreases fluid loss in vacuum packaged products which have been thermally processed, 3) it increases the viscosity of meat batters, facilitating the incorporation of fats, and 4) it increases the pH of meat systems (Terrell, 1982). Therefore, since the binding of lean and fat is dependent on salt, it remains an important processing ingredient (Breidenstein, 1982a). Similar results were reported by Maurer et al. (1969) where the mere presence of salt in protein solutions enhanced emulsifying

capacity when compared to solutions where the salt has been removed by dialysis.

Neer and Mandigo (1977) demonstrated that increasing the amount of salt increased cooking yields, tenderness, and water-binding capacity in flaked, cured pork products. Moore et al. (1976) found binding strength and cooking yield increased as salt concentration increased from 1 to 3% when 0.25% sodium tripolyphosphate (STP) was included in beef rolls. However, Breidenstein (1982b) and Booren et al. (1981) agreed that as salt concentration increased in formed beef steaks, rancidity also increased after 90 days of freezer storage. Schwartz and Mandigo (1976) found increased rancidity and decreased color desirability when salt was added to restructured pork.

Mandigo and Booren (1981) recommended 0.75% salt in restructured products, because this level kept rancidity within an acceptable range while capitalizing on the positive influences of salt. Kastner and Gray (1984) suggested the use of a low salt level in conjunction with hot-boning, because of the improved functional properties of hot-boned beef. The protein is more readily available for extraction compared to conventionally processed post-rigor meat, thus less salt is required for successful restructuring.

Functional properties of beef muscle such as pH and water holding capacity (WHC) are affected by the type of chloride salt used (Terrell et al., 1981). The WHC of meat

proteins is directly related to shrinkage in cooking, drip loss in freezing and thawing, tenderness and perhaps other consumer quality attributes of meats (Wierbicki et al., 1957). Terrell, (1983) reported that replacement of NaCl with any chloride salt, except $CaCl_2$ significantly decreased moisture loss in raw and cooked beef muscles. A similar observation was reported by Wierbicki et al. (1954) where NaCl infusion into the muscle greatly decreased drip loss after freezing and defrosting. Wierbicki et al. (1957) also reported less shrink loss by using divalent cations on cooked muscles at 70 C when compared to monovalent cations. Hamm (1956) reported lower pH values and decreased WHC of raw meat when magnesium and calcium chloride where used. However, Wierbicki et al. (1957) reported that during heating of meat, the meat pH changes, where calcium chloride tended to prevent increases of pH on heated muscles, while magnesium chloride did not. Wierbicki et al. (1957) also reported that the effect of $MgCl_2$ on improving the WHC of heated muscles was clearly evident.

At present, KCl is the only chloride salt alternative for NaCl that is generally recognized as safe (GRAS) for use in processed meats (Terrell, 1983). For products in which 100% of the NaCl was replaced with KCl or $CaCl_2$, Terrell (1983) reported lower scores for flavor and overall palatability when compared to controls. Therefore, the amount of NaCl that could be reduced by using KCl may be limited. Similar results were reported by Hand et al.

(1982b) where off-flavor scores increased between 3 and 6 wk of storage for products made with 35 or 100% KCl. However, Terrell, (1983) and Hand et al. (1982c) reported that frankfurters in which 35% of the total NaCl was replaced with KCl or $MgCl_2$, were not different in flavor or overall palatability than controls.

Salts and Microbial Growth.

A very important and often overlooked function of salt in processed meats is preservation. For optimum product safety, a balance of salt, heat, and nitrate (in cured products) is essential (Maurer, 1983). Cerveny (1980) reported that brine concentration (percent salt in the water phase) indicates a better relationship between salt concentration and antimicrobial activity. By increasing NaCl concentrations, one also increases the brine concentration, thus, causing a reduction in water activity (Aw). It is generally accepted that microbial growth is inhibited by Aw concentrations below 0.90 to 0.91 (Banward. 1979). However, some types of bacteria such as Staphylococcus aureus and the halophilic bacteria are capable of growth under lower Aw values of 0.84 and 0.75, respectively (Banward. 1979).

Terrell et al. (1983) reported no significant differences among 2.5% NaCl or equivalent ionic strengths (IS) of 0.42 for KCl, $MgCl_2$, and $CaCl_2$ on total aerobic plate count for Micrococcus and/or Moraxella spp. in pork sausage refrigerated for 12 days. Barbut et al. (1986a) reported that an increase in NaCl concentration had a marked effect on the inhibition of botulinal toxin production. Similar results were also presented by Pivnick and Barnett (1965), Hauschild (1982), and Barbut et al. (1986a) where an increase of NaCl concentration from 2.4 to 3.25% doubled the time for botulinal toxin detection, and a 4% increase totally inhibited toxin production. However, Whiting (1984) reported that storage time was a more important factor than salt concentration in allowing S. aureus and Clostridium sporogenes to grow on frankfurters. Tanner and Evans (1934) reported that species and strains of bacteria vary in their susceptibility to salt.

Botulinal Toxin Production.

Increasing KCl concentrations improved the inhibition of botulinal toxin production, but to a lesser extent than that provided by NaCl at the same IS (Barbut et al., 1986a). This difference in inhibition becomes more obvious as IS values increased. Data comparing the bacterial inhibitory

effect of KCl seem to be dependent on the organism studied (Jackobsen et al.,1972). Strong et al. (1970) reported that KCl was more inhibitory than NaCl for C. perfringens.

$MgCl_2$ did not show any inhibitory effect on toxin production by C. botulinum even when the level was increased from an IS of 0.42 to 0.62 (Barbut et al., 1986a). $MgCl_2$ increased the Aw but decreased brine concentration compared to NaCl at the same IS. Mg^{++} is a divalent ion for the IS calculations, therefore, less $MgCl_2$ is required to obtain a given IS. Heinis et al. (1977) reported that Mg ions improved the recovery rate from heat or cold injuries for some microorganisms. Similar results were reported by Hughes and Hurst (1976) for S. aureus.

A salt mixture with half the NaCl replaced with KCl at an IS of 0.42 was found to be as inhibitory as 2.5% NaCl. However, replacement of half the NaCl with $MgCl_2$ at an IS of 0.42 was inferior to 2.5% salt for toxin inhibition (Barbut et al., 1986b).

It is apparent that no single solution may exist to optimize all the functional and economical parameters when NaCl levels in processed meats are replaced with other chloride salts. However, reduction and replacement of current levels of NaCl in processed meats with KCl, appears to be a viable option for Na reduction in processed meats (Terrell, 1982).

Seasoning.

Salt added to the surface of the meat just before roasting or broiling will penetrate the meat only a fraction of an inch during cooking (Gisslen, 1983). The same will be true of the flavors of herbs and spices. In the case of a meat roast, where most of the surface is either fat or bone, there will be minimal or no penetration at all. Many chefs disagree on when to season (Gisslen, 1983). Some feel that meat should not be seasoned before broiling because salt draws moisture to the surface and retards browning. Others feel that seasoning before broiling improves the taste of the meat, because the seasoning becomes part of the brown crust rather than something sprinkled on afterward.

According to Gisslen (1983), there are several alternatives to seasoning just before cooking. These alternatives are: 1) season several hours or a day in advance, to give the seasoning time to penetrate, 2) season the meat after cooking, and 3) don't season at all, but carefully season the gravy or juices that will be served with the meat. However, with smaller cuts of meat with greater surface area, seasoning prior to cooking provides each customer a share of seasoned, browned surface (Gisslen, 1983).

CHAPTER III

EXPERIMENTAL PROCEDURE

Ten pairs of boneless strip loins from 10 selected carcasses were purchased from a major meat purveyor, trimmed to 0.64cm of subcutaneous fat, and crust frozen for 5 hr at -40 C. Each pair of strip loins was randomly subdivided for two seasoning intervals consisting of 0 or 24 hr prior to cooking. The anterior end (13^{th} rib) of each pair of strip loins was faced and 7 steaks (2.5cm thick) were cut from each loin, vacuum packaged and frozen (-30 C) until the time of treatment application. After a thawing period of 24 hr at 5 $\pm$ 1 C, each steak was randomly assigned to one of 6 treatment combinations and a control treatment. The 6 treatment combinations were based on a 3x2 factorial design consisting of:

3 salt types (NaCl, lite salt (50/50% NaCl:KCl), and Lite KCl a mixture of 25/75% KCl:NaCl), and

2 salt levels (0.5 and 1.0% of the raw steak weight).

All salt treatments were applied in the dry form externally to the surface of each steak.

After treatment application, the 0 hr seasoning interval steaks were cut in half (perpendicular to the long axis) and randomly assigned to either raw or cooked sampling prior to heat application. The 24 hr seasoning interval steaks were stored at 5 $\pm$ 1 C and were not cut in half until immediately prior to heat application. Raw samples (0 hr interval) were placed immediately in a blast freezer for a period of 2 hr prior to obtaining a series of 4 longitudinal slices (each 0.63cm thick). Individual slices were frozen in liquid nitrogen and pulverized in a Waring Blendor. Frozen pulverized samples were stored at -18 C in clear plastic bags before the determination of K, Na, and Cl ion concentrations.

All half steaks for the 0 and 24 hr seasoning intervals were weighed before and after heat application in order to determine cooking shrinkage. Cooking was accomplished following AMSA procedures (Cross et at., 1978) using Farberware "open hearth" broilers. Each individual half was cooked to an internal temperature of 70 C. After heat application cooked samples were collected in an identical manner as the raw samples for the K, Cl, and Na ion determinations.

The 24 hr seasoning interval raw steaks were weighed after treatment application and placed in plastic bags in order to monitor purge loss. Purge loss was calculated as follows: ((weight of the clear bag + purge loss of the individual steak after the 24 hr marination period) - the

weight of the clear bag). After 24 hr, individual steaks were weighed and then cut in half and treated in an identical manner as the 0 hr interval half steaks prior to heat application.

K and Na Ion Determination.

Duplicate samples consisting of three grams of frozen pulverized sample were obtained for the K, Na, and Cl ion determinations using a modified AOAC., (1980) method. Individual samples were placed in Vycor crucibles (pre-weighed and pre-acid washed) and weighed. Crucibles were placed in a muffle furnace at 550 C and ashed overnight. Samples were cooled and weighed before the addition of 25ml of 6N HCL; and quantitatively transferred to a 100ml volumetric flask. An addition of 25ml of 5% Lanthianum solution was added to each flask and then diluted to volume with deionized water. After the precipitation of silicates, the supernatant was collected and stored. For K and Na ion determinations, samples were diluted 1 to 50 before final determination via atomic absorption. Results were expressed as mg of retained ion per 100g of wet tissue.

Cl Ion Determination.

All samples were prepared using ORION-Cl specific electrode methods for the Cl ion determination (Orion Research, 1980). This method required minimal sample preparation, was not affected by color or turbidity of sample, and did not require filtration. Analysis time was short since percent Cl ion concentration was read directly (as % salt), with no additional computations necessary.

The meter measures the electrical potential developed by the chloride sensing electrode in response to chloride in solution. The meat samples were extracted, by heating the samples with 100ml of the extracting solution (993.7ml of distilled water and 6.3ml of nitric acid). The extracted sample was measured directly in the same acid solution as the standards in order to eliminate background interferences.

Proximate Analysis

Representative duplicate samples for each treatment (3 to 4g each) were trimmed of all subcutaneous fat and

epimysium. Moisture was measured by determination of the weight loss after drying for 24 hr at 102 C as described by AOAC (1980). Fat content was determined by measuring the weight loss of the dried sample resulting from 8 to 16 hr of continuous ether extraction. Samples were weighed, ashed overnight, and reweighed for the ash determinations. Percent protein for each sample was calculated as follows:

% protein = 100 - (% Moisture + % Fat + % Ash).

Statistical Analysis

The experimental design was a split plot with main units in a randomized complete block design where blocks are carcasses, main unit treatments are seasoning intervals and the subunit treatments are the control and the type-level combinations. Data were subjected to the analysis of variance procedure and main effect means were compared by using the least significant difference method (Steel and Torrie, 1980) with procedure and error term determined by significance of interactions.

CHAPTER IV

RESULTS AND DISCUSSION

Carcass data and proximate analysis values are presented in table 1 to characterize the 20 strip loins (IMPS 180) used in this study. These values represent strip loins from carcasses selected to meet the upper one-third of the U.S Select quality grade (USDA, 1987). Mean values agree with recent proximate composition work for USDA quality grades (Savell et al., 1986).

Purge loss and cooking shrinkage means by salt treatment are presented in table 2. Due to a non significant treatment by seasoning interval interaction for purge loss, treatment main effect means were compared. Purge loss was significantly greater ($P<.05$) for the control treatment than any salt treatment combination; In fact, the loss was as much as three times greater than the other treatments. A trend was evident in that 1.0% added salt treatments tended to have less purge loss than those with 0.5% added salt, although these differences were not statistically significant.

TABLE 1. STRIP LOIN CARCASS DATA AND PROXIMATE COMPOSITION[a].

Carcass trait	Mean	Standard deviation	Minimum	Maximum
Subcutaneous fat thickness (mm)	6.35	2.29	3.81	8.89
Longissimus muscle area (sq cm)	90.30	6.26	81.92	105.80
KPH %	1.62	0.21	1.50	2.00
Carcass wt. (kg)	307.32	7.74	295.93	316.47
Overall maturity score[b]	160.00	16.41	130.00	180.00
Marbling score[c]	360.00	27.00	330.00	399.00
Strip loin				
Moisture (%)	72.41	1.11	69.60	74.45
Fat (%)	4.17	1.09	2.20	6.85
Ash (%)	1.04	0.04	0.97	1.11
Protein (%)	22.37	0.45	21.60	23.10

[a]AOAC, 1980
[b]100= "A" maturity based on USDA, 1987.
[c]300= "Slight" marbling score (USDA, 1987).

TABLE 2. PURGE AND SHRINKAGE MEANS FOR TREATMENT GROUPS WITHIN SEASONING INTERVAL.

Salt treatment[a]	Purge, (g)	Cooking shrinkage,(%)	
		0 Interval[b]	24 Interval
Control	3.20[c]	29.10[c]	29.31[c]
0.5% Lite	1.51[d]	27.05[c]	26.12[bd]
0.5% NaCl	1.49[d]	29.98[c]	24.60[de]
0.5% Lite KCl	1.31[d]	27.71[c]	26.77[cd]
1.0% Lite	1.07[d]	27.33[c]	22.32[e]
1.0% NaCl	1.35[d]	26.85[c]	25.01[de]
1.0% Lite KCl	1.20[d]	27.37[c]	24.17[de]
Std error	0.70	1.72	1.72

[a]Control= no salt, Lite salt= 50:50% NaCl:KCl, Lite KCl= 25:75% KCl:NaCl.
[b]0 interval= salted inmediately prior to broiling; 24 interval= salted 24 hours prior to broiling.
[c,d,e]Means (n=20) in the same column bearing a common superscript letter are not statistically (P>.05) different.

Due to a significant treatment by seasoning interval interaction, subclass means for cooking shrinkage were analyzed for the 0 and 24 hr seasoning intervals. Percentage cooking shrink for all treatment combinations at the 0 hr seasoning interval were not different ($P>.05$).

A trend was observed for the 24 hr seasoning interval, where steaks treated with salt tended to have less cooking shrink percentages than control steaks. Likewise, 1.0% salt treatments shrunk slightly less than 0.5% salt treatments during broiling. However, differences in shrinkage were only significant for the control steaks versus 1.0% salt treatments and the 0.5% NaCl group. Furthermore, no ($P>.05$) differences were observed between the 0.5% NaCl treatment group and the 1.0% salt treatments. It is important to note that shrinkage percentages for the 24 hr seasoning interval were lower than those for the 0 hr interval for all treatment combinations except for the control treatment.

Due to the introduction of the variable location for the ion determinations, it produced the 2^{nd} split within the original design; producing in some cases a significant interaction between treatments and seasoning intervals. In tables where this interaction was significant, main effect means were broken down for the 0 and 24 hr seasoning intervals, however, where the interaction was not significant treatment main effect means have been averaged over seasoning intervals for treatment comparisons.

Concentrations of potassium (K) ion in the center and surface locations of raw strip steaks are presented in table 3. For the 0 hr interval, all treatment combinations were similar (P>.05), however, among these treatments the control and the 1.0% Lite KCl treatments showed the highest, potassium ion concentrations for raw centers. The 1.0% lite salt treatment at the 24 hr seasoning interval was significantly higher for potassium concentration than any other treatment combinations.

This result aligns directly with treatment applications since the Lite KCl treatments have 25% less potassium ion as compared to the lite salt treatments at either 1.0% or 0.5%. For treatments where 1.0% salt was added for either seasoning interval, potassium ion concentration tended to be higher than those where 0.5% salt was added. Comparing 0 vs 24 hr seasoning intervals for potassium concentration for raw centers, all treatment main effects except for the control treatment showed increased concentrations. This increased concentration was expected due to the increased seasoning interval whereby, the time evidently was adequate for more complete ion penetration.

The 1.0% Lite salt treatment had a higher (P<.05) potassium ion concentration in the raw surface (Table 3) than other treatment combinations. Following the 1.0% Lite treatment were the 0.5% Lite and the 1.0% Lite KCl treatments which were not different (P>.05) from each other. The lowest potassium ion concentration was observed for the

TABLE 3. POTASSIUM CONCENTRATION FOR RAW STRIP LOIN STEAKS.

Salt treatment[b]	Steak location[a]		
	Center		Surface
	0 Interval[c] (mg/100g)	24 Interval (mg/100g)	(mg/100g)
Control	51.86[d]	42.78[f]	50.40[f]
0.5% Lite	49.19[d]	61.17[e]	73.40[e]
0.5% Lite KCl	46.59[d]	57.45[e]	58.70[f]
1.0% Lite	49.30[d]	77.38[d]	92.60[d]
1.0% Lite KCl	50.79[d]	57.88[e]	78.60[e]
Std error	5.43	5.43	4.41

[a]Center= inner 1.27cm of each steak; Surface= outer 0.64cm of each steak side.
[b]Control= no salt, Lite salt= 50:50% NaCl:KCl, Lite KCl= 25:75% KCl:NaCl.
[c]0 interval= salted inmediately prior to broiling, 24 interval= salted 24 hours prior to broiling.
[d,e,f]Means (n=10) in the same column bearing a common superscript letter are not statistically (P>.05) different.

control treatment followed by the 0.5% Lite KCl salt treatment. It is important to note that regardless of the interaction, the surface location of steaks contained a higher concentration of the potassium ion than the center location.

The 1.0% Lite and 1.5% Lite KCl salt treatments were higher ($P<.05$) for potassium ion concentration in the center location for cooked strip steaks, than the 0.5% treatments or the control (Table 4). A similar trend was noted for the surface location, where the 1.0% Lite salt treatment had the highest potassium concentration. For either center or surface locations among cooked strip steaks, the 0.5% Lite, 0.5% Lite KCl and the 1.0% Lite KCl salt treatments were not ($P>.05$) different. Among treatments, the control and the 0.5% Lite KCl treatments showed the lowest potassium ion concentrations.

Means for sodium (Na) ion concentration in the center and surface locations for raw strip steaks are presented in table 5. Due to a significant treatment by seasoning interval interaction, main effects means for the center location have been broken down for the 0 and 24 hr seasoning intervals. The 1.0% NaCl salt treatment showed the highest ($P<.05$) sodium ion concentration for raw center locations at either seasoning interval. A trend was observed for both intervals, where the 1.0% Lite and 0.5% NaCl salt treatments were not ($P>.05$) different. Means for sodium ion concentration for the raw surface location showed a similar

TABLE 4. POTASSIUM CONCENTRATION FOR COOKED STRIP LOIN STEAKS.

Salt treatment[b]	Steak location[a] Center (mg/100g)	Surface (mg/100g)
Control	45.30[e]	59.80[e]
0.5% Lite	54.90[d]	78.40[cd]
0.5% Lite KCl	53.90[de]	68.44[de]
1.0% Lite	67.50[c]	87.70[c]
1.0% Lite KCl	61.60[cd]	73.90[d]
Std error	4.76	5.81

[a]Center= inner 1.27cm of each steak; Surface= outer 0.64cm of each steak side.
[b]Control= no salt, Lite salt= 50:50% NaCl:KCl, Lite KCl= 25:75% KCl:NaCl.
[c,d,e]Means (N=10) in the same column bearing a common superscript letter are not statistically (P>.05) different.

TABLE 5. SODIUM CONCENTRATION FOR RAW STRIP LOIN STEAKS.

Salt treatment[b]	Steak location[a]		
	Center		Surface
	0 Interval[c] (mg/100g)	24 Interval (mg/100g)	
Control	8.32[e]	8.81[g]	13.40[g]
0.5% Lite	12.02[f]	21.77[g]	28.70[f]
0.5% NaCl	18.66[e]	32.98[f]	42.80[e]
1.0% Lite	17.86[e]	36.50[f]	42.70[e]
1.0% NaCl	26.09[d]	48.66[d]	62.66[d]
Std error	2.66	2.66	2.71

[a]Center= inner 1.27cm of each steak; Surface= outer 0.64cm of each steak side.
[b]Control= no salt, Lite salt= 50:50% NaCl:KCl.
[c]0 interval= salted inmediately prior to broiling, 24 interval= salted 24 hours prior to broiling.
[d,e,f,g]Means (N=10) in the same column bearing a common superscript letter are not statistically (P>.05) different.

trend where the 1.0% added salt treatments produced generally higher Na ion concentrations than the 0.5% added salt treatments, regardless of seasoning interval.

Concentrations of sodium ion for center and surface locations for cooked strip steaks are presented in table 6. Among all treatments, for the center location, the 1.0% NaCl and the 1.0% Lite salt treatments showed the highest ($P<.05$) sodium ion concentrations, followed by the 0.5% NaCl and the 0.5% Lite salt treatments with intermediate Na concentrations. A similar trend was observed for the cooked center location at the 24 hr interval, where the 1.0% NaCl treatment had the highest sodium ion concentration ($P<.05$) followed by the 0.5% NaCl, 1.0% Lite, and the 0.5% Lite salt treatments.

Means for the surface location for cooked strip steaks are also presented in table 6. The 1.0% NaCl treatment had the highest ($P<.05$) sodium ion concentration for both seasoning intervals. Following the 1.0% NaCl treatment were the 0.5% NaCl and the 1.0% Lite salt treatments, which were not ($P>.05$) different for either seasoning interval. The control treatment showed consistently smaller sodium ion concentrations for both seasoning intervals.

Concentrations of chloride ion percentages for center and surface locations are presented in table 7 as determined by the Orion-CL specific electrode method. For the 0 hr seasoning interval, the 1.0% Lite KCl, 1.0% NaCl, 0.5% Lite KCl, 1.0% Lite, and 0.5% Lite salt treatments were not

TABLE 6. SODIUM CONCENTRATION FOR COOKED STRIP LOIN STEAKS.

Salt treatment[b]	Steak location[a]			
	Center		Surface	
	0 Interval[c] (mg/100g)	24 Interval (mg/100g)	0 Interval (mg/100g)	24 Interval (mg/100g)
Control	7.81[f]	9.08[f]	9.33[g]	10.40[f]
0.5% Lite	12.93[ef]	30.92[e]	28.41[f]	38.47[e]
0.5% NaCl	13.58[e]	34.10[e]	41.21[e]	45.12[e]
1.0% Lite	20.78[d]	31.65[e]	37.11[e]	38.26[e]
1.0% NaCl	24.15[d]	49.20[d]	50.21[d]	68.33[d]
Std error	2.85	2.85	3.48	3.48

[a]Center= inner 1.27cm of each steak; Surface= outer 0.64cm of each steak side.
[b]Control= no salt, Lite salt= 50:50% NaCl:KCl.
[c]0 interval= salted inmediately prior to broiling, 24 interval= salted 24 hours prior to broiling.
[d,e,f,g]Means (N=10) in the same column bearing a common superscript letter are not statistically (P>.05) different.

TABLE 7. CHLORIDE ION PERCENTAGES FOR RAW STRIP LOIN STEAKS.

Salt treatment[b]	Steak location[a]			
	Center		Surface	
	0 Interval[c] (%)	24 Interval (%)	0 Interval (%)	24 Interval (%)
Control	0.10[f]	0.07[g]	0.07[g]	0.08[f]
0.5% Lite	0.19[de]	0.32[f]	0.58[f]	0.39[e]
0.5% Lite KCl	0.23[de]	0.37[ef]	0.51[f]	0.40[e]
0.5% NaCl	0.16[ef]	0.45[e]	0.58[f]	0.46[e]
1.0% Lite	0.23[de]	0.62[d]	1.05[d]	0.74[d]
1.0% Lite KCl	0.29[d]	0.57[d]	0.87[e]	0.69[d]
1.0% NaCL	0.24[df]	0.64[d]	1.05[d]	0.76[d]
Std error	0.054	0.054	0.066	0.066

[a]Center= inner 1.27cm of each steak; Surface= outer 0.64cm of each steak side.
[b]Control= no salt, Lite salt= 50:50% NaCl:KCl, Lite KCl= 25:75% KCl:NaCl.
[c]0 interval= salted inmediately prior to broiling, 24 interval= salted 24 hours prior to broiling.
[d,e,f,g]Means (N=10) in the same column bearing a common superscript letter are not statistically (P>.05) different.

(P>.05) different. Among these treatments, the 1.0% Lite KCl had the highest chloride ion percentage followed closely by the 1.0% NaCl and the 1.0% Lite salt treatments. For the 24 hr seasoning interval the 1.0% NaCl, 1.0% Lite KCl, and the 1.0% Lite salt treatments showed the highest (P<.05) chloride ion percentage, followed by the 0.5% NaCl and the 0.5% Lite KCl treatments. The control treatment consistently had the smallest chloride ion percentages for both seasoning intervals.

Chloride percentage means for the 0 hr interval were consistently higher than for the 24 hr seasoning interval. This agrees with our expectations, because the time allowed for ion penetration was not sufficient, therefore concentrations at the surface of the cooked samples should be higher than those of the 24 hr interval. However, for either the 0 hr and 24 hr seasoning intervals the 1.0% NaCl and the 1.0% Lite salt treatments were generally higher (P<.05) for chloride ion percentages, followed closely by the 1.0% Lite KCl treatment. The control treatment for either seasoning interval had the smallest (P<.05) chloride ion means among treatments.

Chloride ion percentage in the center and surface locations for cooked strip steaks are presented in table 8, where the 1.0% NaCl, 1.0% Lite KCl, 1.0% Lite, 0,5% Lite KCl and 0.5% Lite salt treatments were not (P>.05) different for the cooked center location at the 0 hr seasoning interval. A similar trend was observed for the 24 hr interval, where

TABLE 8. CHLORIDE ION PERCENTAGES FOR COOKED STRIP LOIN STEAKS.

Salt treatment[b]	Steak location[a]			
	Center		Surface	
	0 Interval[c] (%)	24 Interval (%)	0 Interval (%)	24 Interval (%)
Control	0.08[f]	0.08[f]	0.17[e]	0.16[f]
0.5% Lite	0.22[de]	0.41[e]	0.40[f]	0.51[e]
0.5% Lite KCl	0.22[de]	0.42[e]	0.45[f]	0.53[e]
0.5% NaCl	0.18[e]	0.40[e]	0.50[ef]	0.52[e]
1.0% Lite	0.29[d]	0.64[d]	0.68[d]	0.81[d]
1.0% Lite KCl	0.30[d]	0.67[d]	0.62[de]	0.85[d]
1.0% NaCl	0.30[d]	0.72[d]	0.69[d]	0.90[d]
Std error	0.044	0.044	0.072	0.072

[a]Center= inner 1.27cm of each steak; Surface= outer 0.64cm of each steak side.
[b]Control= no salt, Lite salt= 50:50% NaCl:KCl, Lite KCl= 25:75% KCl:NaCl.
[c]0 interval= salted inmediately prior to broiling, 24 interval= salted 24 hours prior to broiling.
[d,e,f]Means (N=10) in the same column bearing a common superscript letter are not statistically (P>.05) different.

higher chloride ion percentages were obtained for the 1.0% NaCl, 1.0% Lite KCl, and 1.0% Lite salt treatments.

Chloride means for the cooked surface location were significantly higher for either seasoning interval for the 1.0% Nacl, 1.0% Lite KCl, and the 1.5% Lite salt treatments. Intermediate chloride ion values for either seasoning interval were observed for the 0.5% Lite KCl and 0.5% Lite salt treatments.

In order to estimate ion retention for each of our treatments, linear and quadratic regression equations were estimated and are presented in tables 9 thru 12. Regression coefficients and residual standard deviations are also shown in order to estimate how well the curve fitted the data and how far off our predictions were from the true values. However, for some of the parameters studied; neither the linear or quadratic equations were significant, therefore they were listed as non significant (N/S). The Lite KCl treatments showed an inconsistent linear relationship for the raw and cooked samples for both seasoning intervals. For the NaCl salt treatment, only the cooked center and raw surface locations showed a linear relationship for either interval. However, the Lite salt treatment showed potassium raw surface, cooked surface, and cooked center with a linear relationship, while the Na cooked center showed a quadratic relationship for both seasoning intervals.

Table 9. PREDICTION EQUATIONS[a] FOR SODIUM ION RETENTION IN STEAKS SEASONED WITH SODIUM CHLORIDE.

Seasoning interval	Regression equation	R^2X100	Residual SD
0 hr Interval			
Raw Center	$Y=13.94 + 11.61(X)$	24.80	8.53
Raw Surface	$Y=18.20 + 53.02(X)$	73.80	13.31
Cooked Center	$Y=7.0 + 16.34(X)$	62.40	5.35
Cooked Surface	$Y=9.30 + 86.6(X) - 45.7(X^2)$	83.30	8.26
24 hr interval			
Raw Center	$Y=8.8 + 56.8(X) - 16.9(X^2)$	92.60	4.44
Raw Surface	$Y=11.8 + 45.34(X)$	86.40	7.60
Cooked Center	$Y=10.7 + 40.12(X)$	87.60	6.30
Cooked Surface	$Y=12.3 + 57.93(X)$	86.20	9.76

[a]Y= ion retention, X= salt concentration

Table 10. PREDICTION EQUATIONS[a] FOR POTASSIUM ION RETENTION IN STEAKS SEASONED WITH LITE POTASSIUM CHLORIDE (25:75% KCl:NaCl).

Seasoning interval	Regression equation	R^2X100	Residual SD
0 hr Interval			
Raw Center	Non Significant	0.12	12.85
Raw Surface	Y=51.04 + 31.29(X)	36.50	17.41
Cooked Center	Y=43.1 + 11.25(X)	15.70	10.9
Cooked Surface	Non Significant	0.23	11.75
24 hr interval			
Raw Center	Y=45.1 + 15.1(X)	23.20	11.5
Raw Surface	Y=45.8 + 25.20(X)	42.30	12.40
Cooked Center	Y=47.8 + 21.32(X)	34.40	12.40
Cooked Surface	Non Significant	1.18	11.52

[a]Y= ion retention, X= salt concentration

Table 11. PREDICTION EQUATIONS[a] FOR SODIUM AND POTASSIUM ION RETENTIONS IN STEAKS SEASONED WITH LITE SALT (50:50% NaCl:KCl).

	0 hr Seasoning Interval		
Salt type by location	Regression equation	R^2X100	Residual SD
Na Raw Center	Non Significant	2.90	8.25
Na Raw Surface	Y=17.79 + 29.56(X)	59.90	0.30
Na Cooked Center	Y=7.35 + 12.90(X)	53.60	5.10
Na Cooked Surface	$Y=9.30 + 48.5(X) - 20.7(X^2)$	83.30	5.40
K Raw Center	Non Significant	0.75	12.38
K Raw Surface	Y=55.8 + 49.95(X)	57.80	18.02
K Cooked Center	Y=42.0 + 22.22(X)	37.50	12.10
K Cooked Surface	Y=59.7 + 30.73(X)	38.60	16.36

[a]Y= ion retention, X= salt concentration

Table 12. PREDICTION EQUATIONS[a] FOR SODIUM AND POTASSIUM ION RETENTIONS IN STEAKS SEASONED WITH LITE SALT (50:50% Na:KCL).

	24 hr Seasoning Interval		
Salt type by location	Regression equation	R^2X100	Residual SD
Na Raw Center	$Y=8.5 + 27.7(X)$	92.00	3.30
Na Raw Surface	$Y=10.3 + 18.8(X) + 10.3(X^2)$	93.70	3.20
Na Cooked Center	$Y=9.08 + 64.8(X) - 42.2(X^2)$	70.00	7.17
Na Cooked Sueface	$Y=10.4 + 84.4(X) - 56.6(X^2)$	78.00	7.23
K Raw Center	$Y=43.1 + 34.6(X)$	52.20	13.90
K Raw Surface	$Y=46.1 + 34.4(X)$	64.20	10.88
K Cooked Center	$Y=47.6 + 22.31(X)$	16.00	21.58
K Cooked Surface	$Y=63.13 + 24.89(X)$	19.40	21.40

[a]Y= ion retention, X= salt concentration

CHAPTER V

SUMMARY AND CONCLUSIONS

Treatments involving the addition of 1.0% salt overall had less purge loss, less cooking shrinkage, and greater ion retention when compared to those treatments where 0.5% salt was added. The control treatment consistently showed more purge loss, higher cooking shrinkage, and significantly lower ion concentrations when compared to any salt treatment combination. This reduction in ion concentration could be associated with the increased purge loss in the control treatment. It is important to note that for cooking shrinkage and potassium ion concentration at the 0 hr seasoning interval, all treatment combinations were similar ($P>.05$). The 24 hr seasoning interval showed less cooking shrinkage and greater ion concentration when compared to the 0 hr seasoning interval.

Similar patterns were noticed for the raw and cooked surface locations, where higher ion concentrations were recorded when compared to raw and cooked center locations.

Higher potassium ion concentrations for raw and cooked samples were given by the 1.0% Lite salt treatment followed by the 0.5% Lite and the 1.0% Lite KCl treatments. Sodium ion concentrations were maximized by the 1.0% NaCl followed by the 1.0% Lite salt treatment in either raw or cooked strip steaks. Higher chloride ion concentrations were given by treatments were 1.0% salt were added, specifically 1.0% Lite KCl and 1.0% NaCl salt treatments.

Based on these results, few significant differences were found between salt types. However, consumers should consider thawing and seasoning meat products prior to cooking to reduce purge loss, reduce cooking shrinkage, and maximize penetration of seasoning components to enhance juiciness and overall palatability of the cooked product. Further research should be conducted to investigate the effect of shorter seasoning intervals on these properties. Additionally, sensory panel evaluation should be conducted to monitor the impact of pre-salting on juiciness, tenderness, and flavor of broiled steaks.

REFERENCES

AMA. 1978. Cooking without your salt shaker. Amer. Medical Assn., Ohio Affiliate, Cleveland, OH.

AMA. 1983. Sodium in processed foods. Amer. Medical Assoc. Council on Scientific Affairs. J.A.M.A. 249:784.

Andres, C. 1982. Sodium. Food Processing. 43(2):75.

Anonymous. 1983. Pork making process in consumer awareness. Meat Processing. 2(3):76.

AOAC. 1980. "Official Methods of Analysis."Association of Official Analytical Chemist, Washington, D.C.

Banward, G.J. 1979. Water activity and microbial growth. Basic Food Microbiology. 4:124. The AVI Pulishing Company, INC. Westport, Conneticut.

Barbut, S., Tanka, N., and Maurer, J. 1986a. Effects of varying levels of chloride salts on Clostridium botulinum toxin production in turkey frankfurters. J Food Sci. 51(5):1129.

Barbut, S., Tanka, N., Cassens, R.G., and Maurer, J.A. 1986b. Effects of sodium chloride reduction and polyphosphate addition on Clostridium botulinum toxin production in turkey frankfurters. J. Food Sci. 51(5):1136.

Bóoren, A.M., Jones, K.W., Mandigo, R.W., and Olson, D.G. 1981. Effect of blade tenderization, vacuum mixing, salt addition and mixing time on binding of meat pieces into sectioned and formed beef steaks. J. Food Sci. 46:1678.

Breidenstein, B.C. 1982a. Intermediated value beef products. Nat. Live Stock and Meat Board. Chicago, Ill.

Breidenstein, B.C. 1982b. Industry's view-short-term research priorities in the restructured meat areas. Meat Sci. and Technol. International Symposium. National Live Stock and Meat Board. Chicago, Ill. p. 311.

Cerveny, J.G. 1980. Effects of changes in the production and making of cured meats on the risk of botulism. Food Technol. 34(5):240.

Cross, H.R., Moen, R., and Stanfield, M. 1978. Training and testing of judges for sensory analysis of meat quality. Food Technol. 32(7):48.

FMI. 1981. Sodium sense. FDA and national high blood pressure education program. Food Marketing Inst., Washington, DC 20006.

Food Chemical News. 1982. Meat, poultry products sodium monitoring data reported by USDA. December 13, p.36.

Fregley, M.J. 1981. Sodium and potassium. Ann. Rev. Nutr. 1:69.

Gardenswartz, M.H. and Schrier, R.W. 1982. Renal regulation of sodium excretion. In "Sodium: Its Biologic Significance". ed. S. Papper. p.19. CRC Press, Boca Raton, Fla.

Gisslen, W. 1983. Cooking meats. Professional Cooking. By John Wiley & Sons, Inc.

Hamm, R. 1956. Fleischmineralen und Fleischqualitaet. Calcium, Magnesium, und Zink und ihre Bedeutung fur Wasserbindung und Farbes des Fleisches. Dic Fleischwirtschft. 8, 266-271, 340-344.

Hamm, R. 1960. Biochemistry of meat hydration. Adv. Food Res. 10:355.

Hand, L.W., Terrell, R.N., and Smith, G.C. 1982a. Effects of chloride salt, method of manufacturing and frozen storage on sensory properties of restructured pork roasts. J. Food Sci. 47:1771.

Hand, L.W., Terrell, R.N., and Smith, G.C. 1982b. Effects of complete or partial replacement of sodium chloride on processing and sensory properties of hams. J. Food Sci. 47:1776.

Hand, L.W., Terrell, R.N., and Smith, G.C. 1982c. Effects of chloride salts on physical, chemical, and sensory properties of frankfurters. J. Food Sci. 47:1800.

Hauschild, A.H.W. 1982. Assessment of botulism hazards from cured meat products. Food Technol. 36(12):95.

Heinis, L.W., Beuchat, L.R., and Jones, W.K. 1977. Growth of heat-injured Vibrio parahaemolyticus in media supplemented with various cations. Appl. Environ. Microbiol. 33:1079.

Hughes, A., and Hurst, A. 1976. Magnesium requirement of Staphylococcus aureus for repair from sublethal heat injury. Can. J. Microbiol. 22:1202.

IFT. 1980. Dietary salt; a scientific status summary by the IFT Expert Panel on Food Safety and Nutrition and the committee on Public Information. Food Technol. 34(1):85.

Jones, S.B., Carroll, R.J., and Cavanaugh, J.R. 1976. Muscle samples for scanning electron microscopy: preparative techniques and general morphology. J. Food Sci. 41:867.

Kastner, C.L., and Gray, D.G. 1984. Restructured, pre-cooked cow beef roasts. Proc. 13th Ann. Midwest Meat Processors Seminar. Kansas State University, Manhattan.

Lovrien, P.A. 1982. Sodium and dietary fitness. Proc. Meat Ind. Res. Conf. p. 7.

Mandigo, R.W., and Booren, A.M. 1981. Restructured meats. Proc. Nat'l. Beef Grading Conf. Iowa St. Univ., Ames, Iowa. p. 44.

Maurer, A.J. 1983. Reduced sodium usage in poultry muscle food. Food Technol. 37(7):60.

Maurer, A.J., Baker, R.C., and Vadehra, D.V. 1969. Kind and concentration of soluble protein extract and their effect on the emulsifying capacity of poultry meat. Food Technol. 23(4):177.

McCarron, D.A., Morris, C.D., Henry, H.J., and Stanton, J.L. 1984. Blood pressure and nutrient intake in the United State. Science. 224:1392.

Meneely, G.R. and Battarbee, H.D. 1976. Sodium and potassium. Nut. Rev. 34:225.

Moore, S.L., Theno, D.M., Anderson, C.R., and Schmidt, G.R. 1976. Effect of salt, phosphate, and non-meat protein on binding strength and cooking yield of a beef roll. J. Food Sci. 41:424.

NAS. 1980. Toward Healthful Diets, National Research Council. Nat'l. Acad. of Sci., Washington, D.C.

Neer, R.L., and Mandigo, R.W. 1977. Effect of salt, tripolyphosphate and frozen storage time on properties of flaked, cured pork products. J. Food Sci. 42:738.

Orion Research. 1980. Salt in processed meats; measurement procedure by electrode. Orion Research, 840 Memorial Dr., Cambridge, MA. 02139.

Pearson, A.M., and Wolzak, A.M. 1982. Salt; Its use in animal products; a human health dilemma. J. Anim. Sci. 54:1263.

Pivnick, H., and Barnett, H. 1965. Effect of salt and temperature on toxinogenesis by Clostridium botulinum in perishable cooked meats vacuum-packed in air-impermeable plastic pouches. Food Technol. 19(7):1164.

Savell, J.W., Cross, H.R., and Smith, G.C. 1986. Percentage ether extractable fat and moisture content of beef longissimus muscle as related to USDA marbling score. J. Food Sci. 3:838.

Schwartz, W.C., and Mandigo, R.W. 1976. Effect of salt, sodium tripolyphosphate and storage on restructured pork. J. Food Sci. 41:1266.

Sebranek, J.G., Olson, D.G., Whiting, R.C., Benedict, R.C., Rust, R.E., Kraft, A.A., and Woychik, J.H. 1983. Physiological role of dietary sodium in human health and implications of sodium reduction in muscle foods. Food Technol. 37(7):51.

Shank, F.R., Park, Y.K., Harland, B.F., Vanderveen, J.E., Forbes, A.L., and Prosky, L. 1982. Perspective of food and drug administration on dietary sodium. J. Am. Dietetic Assoc. 80(1):29.

Steel, R.G., and Torrie, J.A. 1980. "Principles and Procedures of Statistics". 2nd McGraw-Hill Book Co., New York.

Strong, D.H., Foster, E.F., and Duncan, C.L. 1970. Influence of water activity on the growth of Clostridium perfringens. Apl. Microbiol. 19:980.

Tanner, F.W., and Evans, F.L. 1934. Effect of sodium chloride in meat curing solutions on anaerobic bacteria. Zentr. Bakteriol. Parasitenk. 91:1.

Terrell, R.N., and Olson, D.G. 1981. Chloride salts and processed meats: properties, sources, mechanisms of action and labeling. In Proc. Meat Ind. res. Conf., p. 67. Am. Meat Inst. Arlington, VA.

Terrell, R.N., Ming, C.G., Jacobs, J.A., Smith, G.C., and Carpenter, Z.L. 1981. Effect of chloride salts, acid phosphate and electrical stimulation on pH and moisture loss from beef clod muscles. J. Anim. Sci. 53:658.

Terrell, R.N. 1982. Reduction or replacement of salt in processed meats. In Proc. 24th Ann. Meat Sci. Inst. Dept. of Food Sci., Univ. of Georgia, Athens.

Terrell, R.N., Childres, A.B., Kayfus, T.J., Ming, C.G., Smith, G.C., Kotula, A.W., and Johnson, H.K. 1982. Effects of chloride salts and nitrite on survival of Trichina larvae and other properties of pork sausages. J. Food Protect. 45:281.

Terrell, R.N. 1983. Reducing the sodium content of processed meats. Food Technol. 37(7):66.

Terrell, R.N., Quintanilla, M., Vanderzant, C., and Gardner, F.A. 1983. Effects of reduction or replacement of sodium chloride on growth of Micrococcus, Moraxella, and Lactobacillus inoculated ground pork. J.Food Sci. 48:122.

Tobian, L. 1979. The relationship of salt and hypertension. Amer. J. Clin. Nutr. 32:2739.

USDA. 1987. Official United State standards for grades of carcass beef. USDA, Agricultural Marketing Service, Washington, DC.

USDA. 1980. Nutrition and your health. dietary quidelines for americans. Home and Garden Bull. No. 232. U.S. Govt. Printing Office, Washington, D.C.

Wierbicki, E., Cahill, V.R., and Deatherage, F.E. 1957. Effects of added sodium chloride, potassium chloride, calcium chloride, magnesium chloride, and citric acid on meat shrinkage at 70C and of added sodium chloride on drip losses after freezing and thawing. Food Technol. 11:74.

Wierbicki, E., Kunkle, L.E., Cahill, V.R., and Deatherage, F.E. 1954. The relation of tenderness to protein alterations during post mortem aging. Food Technol. 10:80.

Whiting, R.C. 1984. Addition of phosphates, proteins, and gums to reduced salt frankfurters batters. J. Food Sci. 49:1355.

Whiting, R.C., and Richards, L.F. 1978. Influence of divalent cations on poultry meat emulsions and sausage. J. Food Sci. 43:312.

VITA

Hector A. Flores

Candidate for the Degree of

Doctor of Philosophy in Food Science

Thesis: EffECTS OF SALT TYPE, LEVEL, AND SEASONING INTERVAL ON ION PENETRATION OF RAW AND BROILED BEEF STRIP LOINS

Major Field: Food Science

Biographical:

Personal data: Born in Mayaguez, Puerto Rico, April 29, 1961, the son of Hector E. and Elvira Flores.

Education: Graduated from Jose De Diego High School, Mayaguez, Puerto Rico in May, 1979; received Bachelor of Science in Agriculture Degree from Kansas State University in May, 1983; received Master of Science Degree From Kansas State University in July, 1985; completed the requirements for the Doctor of Philosophy Degree at Oklahoma State University in July, 1989.

Professional Experience: Graduate Research and Teaching Assistant, Department of Animal Science, Oklahoma State University, 1986 - 1989, and Kansas State University, 1983 - 1985.

Organizations: Institute of Food Technology, American Society of Animal Science