EFFECT OF CHLORIDE SALTS, CURING COMPOUNDS AND HEATING AND FREEZING ON *TRICHINELLA SPIRALIS* IN PORK PRODUCTS

A Thesis

by

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AND HEATING AND FREEZING ON TRICHINELLA SPIRALIS IN

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Approved as to style and content by:

(Chairman of Committee)

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ABSTRACT

Effect of Chloride Salts, Curing Compounds and Heating and Freezing on Trichinella spiralis in Pork Products. (August 1981)

Timothy Jon Kayfus, B.S., Texas A&M University

Chairman of Advisory Committee: Dr. R. N. Terrell

Trichinae-infected pork shoulders and bone-in hams were used to determine the effects of various processing methods on Trichinella spiralis viability. In experiment one, pork shoulders were used to make linked pork sausage. Phase one of this study used chloride salt replacements calculated to an ionic strength equivalent to that of sodium chloride (2.5%). Phase two of this study consisted of sodium chloride replacements of 0, 25, 50, 75 or 100% with a 70:30 mixture of magnesium chloride and potassium chloride, respectively. In experiment two, the effects of curing, heating and freezing on trichinae viability in bone-in hams were studied. In phase one of this experiment, 36 paired hams were allotted equally into two groups. The first group (18 right hams) was divided into three categories and pickle injected with either 0% NaCl-0 ppm NO_2, 1.6% NaCl-120 ppm NO_2 or 2.6% NaCl-156 ppm NO_2. Pumped hams were placed in cover pickles for four days at 3°C. After four days, one-half of all pumped hams were smoked to an internal temperature of 43.3°C. The second group (18 left hams) was not pumped and was sampled immediately to determine base levels of trichinae. Processed hams were sampled after their respective treatment. Phase two of the second experiment involved

freezing uncooked-pumped hams and raw-unpumped (green) hams. Six green hams and nine hams injected with pickle ingredients of 0% NaCl-0 ppm NO_2, 1.6% NaCl-120 ppm NO_2 and 2.6% NaCl-156 ppm NO_2 were frozen and stored (-29°C). All treated hams and three randomly selected green hams were sampled daily until no viable trichinae were detected. Phase two of this study was designed to determine the effect of pumping ingredients on the destruction of trichinae during freezing and storage.

In phase one of experiment one, the addition of 75 or 150 ppm NO_2 had no effect ($P>0.05$) on pH of sausages, regardless of chloride salt used. The use of 1.35% magnesium chloride or 1.58% calcium chloride decreased ($P<0.05$) pH in comparison to that for sausages made with either sodium chloride or potassium chloride. The addition of 75 or 150 ppm NO_2 did not lower plate counts ($P>0.05$). However, within 75 ppm or 150 ppm nitrite levels, linked sausages made with calcium chloride or sodium chloride had lower counts than links made with magnesium chloride. Percentages of dead trichinae were greater for potassium chloride and sodium chloride than for magnesium chloride and calcium chloride except when 75 ppm NO_2 was used.

Values for pH and cooked juice loss were not affected ($P>0.05$) by any of the sodium chloride replacement (with 70:30, $MgCl_2$:KCl) levels of 0, 25, 50, 75 or 100%. Replacement of 100% NaCl with a mixture of magnesium chloride and potassium chloride increased ($P<0.05$) percentages of dead trichinae above those percentages for 0% replacement. Aerobic plate counts were not different ($P>0.05$) from those in which 25, 50, 75 or 100% of the sodium chloride was replaced when compared to controls (meat only). However, those links with 100% sodium chloride (0% replacement) had low-

er ($P<0.05$) plate counts when compared to all other sausages.

In the second experiment, the use of heat on bone-in hams significantly increased ($P<0.001$) death losses of trichinae. The use of pumping ingredients affected ($P<0.01$) cooler shrinkage and ($P<0.001$) heating shrinkage; interactions (temperature x pumping ingredients) for these traits were not significant. Although treated hams generally had lower numbers of viable trichinae compared to controls, hams pumped with 2.6% NaCl-156 ppm NO_2 and heated to 43.3°C was the only group that was different from its paired control when analyzed by paired-t distribution.

For raw, unpumped hams that were frozen and stored at -29°C, six days were required to kill all viable trichinae. However, hams injected with 0% NaCl-0 ppm NO_2 required seven days of storage to kill all trichinae; hams pumped with 1.6% NaCl-120 ppm NO_2 and 2.6% NaCl-156 ppm NO_2 required eight days of frozen storage to kill all viable trichinae.

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Sincere gratitude is expressed to the author's parents, Mr. and Mrs. Robert L. Kayfus, and the author's brothers and sisters for their love and understanding.

DEDICATION

This thesis is dedicated to my parents, Mr. and Mrs. Robert L. Kayfus, whose love, understanding and constant encouragement have made the completion of this manuscript possible.

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CHAPTER 1

GENERAL INTRODUCTION

Production of ham (excluding that which is dry-cured) and fresh pork sausage processed under federal inspection totaled 1.7 and 0.8 billion pounds, respectively, in 1979 (AMI, 1980). Fresh pork sausage, and hams are popular consumer products because of their flavor and convenience. Most fresh pork sausage in the U.S. (link, chub or patties) is sold as a raw product. It is assumed that these products, when cooked by the consumer, will attain an internal temperature beyond that required to kill trichinae (58.4°C). On the other hand, commercial hams (water-added or regular) are usually heated to 66.7°C during the smoking process and are considered to be free of viable trichinae.

Current U.S. food regulatory policy is directed toward the safety and stability of foods. Reduction in sodium content and the labeling of such products has been suggested (FDA, USDA, FTC, 1979). The technological basis for using sodium chloride in processed meats is well-known (Terrell and Brown, 1981; Hamm, 1960; Saffle, 1968; Ford et al., 1978; Siegel et al., 1978) but the performance of chloride salts other than sodium is not fully understood. Terrell et al. (1981) reported that addition of magnesium chloride to beef muscles resulted in lower pH values and less expressible and cooked moisture loss (higher water holding capacity) when compared with sodium chloride.

The citations on the following pages follow the style of the Journal of Food Science.

Reproductive potential and muscle distribution of trichinae in swine has been reported by Zimmermann (1970). Diaphragm muscle and tongue have high concentrations of larvae whereas hams, loins and shoulders have lower concentrations. Ground pork appears to have lower concentrations of larvae than solid pieces of muscle. Such products as link pork sausage have been reported to contain 12 to 20 live trichinae larvae per gram of positive sample (Zimmermann et al., 1961). Since these sausages are fully cooked before consumption they are exempt from USDA trichinae regulations (USDA, 1975). However, with the advent of microwave cookery, it is not known if this method of preparation will destroy trichinae in raw sausages and other pork products. Perhaps use of low dose irradiation (LDI=less than 1 megarad) used as a pre-treatment would be an effective method of destroying trichinae in raw pork to be cooked by microwave.

The practice of curing edible flesh utilizes two basic theories of meat technology: (1) salting to reduce microbial growth and (2) adding a cure (sodium nitrite) to inhibit botulinal toxin formation, enhance flavor and develop cured color. Smoking, the process of cooking the product and coincidentally fixing the chemical pink-cured color, is an essential part of cured ham operations. Heating to 58.4°C internally is required to kill trichinae (USDA, 1975). Freezing, on the other hand, at a specified temperature and duration will also kill trichinae (Ransom, 1916). These processes have been shown to kill trichinae, but little is known about the combined effect of heat, salt and pumping ingredients on destruction of trichinae. Although not a common practice in commercial operations, freezing of raw cured hams and the possible effects this may have on trichinae viability has not been investigated.

Accordingly, the objectives of this study were: (1) to determine the effect of various chloride salts on Trichinella spiralis viability in fresh linked pork sausage, (2) to determine the effect of various chloride salts on physical and chemical characteristics of fresh link pork sausage, (3) to determine the effect of sodium chloride, sodium nitrite and heat on Trichinella spiralis viability in hams, and (4) to determine the effect of sodium chloride, sodium nitrite and freezing on Trichinella spiralis viability in hams.

CHAPTER II

REVIEW OF LITERATURE

Gould (1971) reviewed the history of human trichinosis and reported the following chronology: (a) Trichinella spiralis (trichinae), a small nematode, was first discovered by James Paget in 1835, (b) Paget, a first-year medical student at St. Bartholomew's Hospital in London, noticed numerous white specks in the muscles of a 50 year-old man that had died of tuberculosis, (c) upon microscopic examination, he found oval cysts enclosing small, coiled worms, (d) in 1846, J. Leidy first discovered trichinae larvae in pork, (e) upon examination of cooked pork, Leidy found encysted trichinae, all of which were dead, (f) Herbst, in 1851, showed that animals who ate flesh infected with trichinae could develop trichinosis in their own musculature, (g) in 1850, he fed trichinae-infected dog meat to a badger and subsequently fed the badger meat to three small dogs which developed trichinosis, and (h) trichinae consist of small, coiled worms, each enclosed in an oval sheath. Females, which are viviparous, measure about 4mm in length; males measure about 1.5mm in length.

Trichinae have been found in the muscles of approximately 60 different species of mammals (Gould, 1971). Transmission of the infection is spread directly from animal to animal. However, Hill (1968) showed that infection may be spread by ingestion of infected larvae from feces. At the present time, the greatest source of trichinae is wildlife (Zimmermann and Hubbard, 1969). In the Arctic, trichinae have been found in 2.5% of walrus, 45% of polar bears and from 45 to 93% of dogs (Rausch, 1970).

Between 1970-1975, Zimmermann (1977) examined black bears in the western and northwestern United States. Trichinae were found in 3.1% of all bears examined. Six bears from California and one bear from Wisconsin contained more than one trichinae per gram, a level considered capable of inducing trichinosis in man.

Pork and pork products represent the largest source of trichinae infection in humans. Raw or undercooked pork, when ingested, can result in clinical trichinosis. Beef products, although not considered a natural reservoir, have been implicated in trichinosis outbreaks (Juranek and Schultz, 1971). Beef can become contaminated through the use of a common meat grinder or through mixing with pork. Among 192 cases of infection (1969), 136 were associated with sausage, eight with pork chops, six with bacon, five with hamburger, two with franks and two with chopped meat (Gould, 1971). In the past 35 years, a steady decline in the reported incidence and deaths due to trichinosis has been reported in the U.S. (Juranek and Schultz, 1971). From 1961 to 1971, only 27 persons died as a result of trichinosis. Of the 115 reported cases of trichinosis during 1971, 82 (71%) were due to consumption of pork products. Of these acquired through non-pork products, over half (52%) were attributed to bear meat (Juranek and Schultz, 1971).

Ingestion of meat contaminated with trichinae is the first step toward development of clinical trichinosis. As the larvae enter the stomach, the digestive juices (HCl and pepsin) degrade the cysts that surround the individual larva. The exposed larvae are not destroyed by the digestive juices and pass on to the small intestine. Here they mature to adults and mate. The female worm burrows into the intestinal mucosa where

she will produce from 1350 to 1500 larvae. The larvae enter the lymph system and eventually enter the circulatory system via the heart. Gradually the larvae migrate toward the musculature of the host. The larvae will then enter muscle and a cyst will be formed about them. Once encysted in the musculature, larvae can not mature into adults. Their only means of reaching maturity is the consumption of the muscle by another organism. The larvae then migrate to the stomach where the cycle begins again.

Kratz (1866) as cited by Gould (1971) found that the incubation period of trichinae in man ranges from a few hours to 43 days; the mean incubation time is nine days. Clinical manifestations of acute trichinosis are usually grouped into three stages: (a) intestinal, (b) muscular invasion and (c) convalescence (Gould et al., 1960). Penetration of the intestinal mucosa by trichinae results in diarrhea and abdominal cramps. Diarrhea is generally associated with fatigue, nausea and vomiting. Muscular penetration is associated with edema of the eyelids. Pain associated with movement occurs within days after invasion. Other symptoms include headache, exhaustion, high fever and weight loss. Eosinophilia (an increase of certain white blood cells) usually accompanies trichinosis. This phenomenon, which is of diagnostic value, is detectable about 10 days after infection. Values may peak at levels with as many as 60 to 70% eosinophils during the third or fourth week post-infection. However, definitive diagnosis is made through skeletal muscle biopsy. Treatment of trichinosis consists of bedrest, therapy to alleviate muscular pain and administration of corticosteroids and thiabendazole (Cambell and Cuckler, 1969).

All forms of fresh pork, including fresh unsmoked sausage containing pork muscle tissue, and pork such as bacon and jowls, other than those covered by USDA regulation 318.10(b), are classified as products that are customarily well-cooked in the home or elsewhere before being served (CFR-9, 1975). Therefore, the treatment of such products for the destruction of trichinae is not required. All other meat food products containing a mixture of pork and beef meat must be treated for destruction of possible live trichinae. Three general methods for destroying trichinae are: (a) heating to 58.3°C, (b) freezing for a specific time at a specific temperature and (c) salting, followed by a drying period.

Ransom and Schwartz (1919) and Otto and Abrams (1939) found that trichinae larvae are quickly destroyed by exposure of meat to an end-point internal temperature of 55°C. Otto and Abrams (1939) discovered that diathermy had no injurious effect upon trichinae larvae. Carlin et al. (1969) reported that the thermal death point of trichinae in pork roasts was between 54.4 to 60°C. Based on Ransom's work, the Bureau of Animal Industry (1917), USDA-Meat Inspection Division (1960) and CFR-9 (USDA, 1975) states that all parts of raw pork muscle tissue should be heated to an internal temperature of not less than 58.3°C.

Freezing represents the second method of destroying trichinae larvae. Ransom (1916) reported that pork stored for a period of not less than 20 days and at a temperature not exceeding -15°C, would be safe from viable trichinae. However, Coles et al. (1980) found that ruminant nematode larvae remained infective for 3.5 years when cryopreservation (freezing) was employed. Further studies conducted by the Zoological Division of the Bureau of Animal Industry of the Department of Agriculture as reported in

Gould and Kaasa (1949) concluded that the length of time required to destroy trichinae varied according to temperature and the thickness of the meat. If pork is packed in sections or boxes not over six inches in thickness, it must be subjected to one of the following temperatures for the stated period of time: $-15^{\circ}C$ for 20 days, $-23.3^{\circ}C$ for 10 days or $-29^{\circ}C$ for six days. If the sections of pork are packed in containers greater than six inches but less than 27 inches in thickness, the required periods of freezing at these temperatures are as follows: $-15^{\circ}C$ for 30 days, $-23.3^{\circ}C$ for 20 days or $-29^{\circ}C$ for 12 days.

Salting and drying (curing) is the third method of treating pork and pork products to destroy trichinae. Ransom and Schwartz (1919) found that decapsuled trichinae larvae remained alive and active in a 2% salt solution for as long as 11 days. Ransom et al. (1920) reported that 3.3 lb of salt per 100 lb of meat, followed by a drying period, were required to kill trichinae (dry sausage procedures). Factors that affected the drying time included casing diameter and the application of smoke. An increase in casing diameter increased drying time whereas smoke application decreased drying time.

Sodium chloride, commonly referred to as table salt, is an essential part of our daily nutrient requirement. The exact daily amount required by humans is difficult to assess and is the source of much disagreement. Ashe and Mosenthal, as reported by Dahl (1958), examined 1000 ambulatory adults in New York City and found the mean sodium chloride intake to be 10 grams per day. Dahl (1958) estimated that the minimum daily requirement for sodium chloride (which is 39% sodium) is as low as 0.06 to 0.12 grams. However, the Institute of Food Technologists (1980) reported that

the most frequent estimate for minimum daily adult requirements is 200 mg of sodium (0.5 g of NaCl).

There has been much recent concern about excessive levels of salt in the North American diet. This concern centers directly upon dietary sodium and its association with hypertension (high blood pressure). Hypertension afflicts 24 million people in the United States and is the most common chronic disease (Marx, 1976). Whether sodium actually causes hypertension remains a center of controversy, but, it is known that blood pressure of persons with genetically related hypertension will be reduced when fed a diet severly restricted in sodium (Moses, 1978).

The use of sodium chloride salt substitutes in processed meats has been studied as an alternative to dietary sodium. Wierbicki et al. (1957a) reported that a solution of 2.8M NaCl and 0.4M $MgCl_2$ injected into a beef round at a 10% level enhanced tenderness above those values for controls. He also reported that chlorides of sodium, potassium, calcium and magnesium, when added to meat prior to heating, increased water holding capacity of meat proteins when heated to 70°C. The amount of juice loss during cooking was less for calcium and magnesium chlorides than that for sodium and potassium chlorides.

Whiting and Richards (1978) reported that emulsifying capacity of a 3% NaCl extract of chicken white muscle was decreased by adding 10mM of $CuCl_2$. However, emulsifying capacity of this same extract was slightly increased by adding $FeCl_2$ and greatly increased by adding $ZnCl_2$. Calcium chloride and other cationic chlorides had no effect on emulsifying capacity.

Studies regarding safety of processed meats must not only determine

processing methods and ingredient effects on trichinae, but must also determine effects that sodium salt substitutes may have on such organisms.

CHAPTER III

GENERAL EXPERIMENTAL PROCEDURES

This research consists of two separate, but interrelated experiments. In experiment one, trichinae-infected pork shoulders were used for making linked pork sausages. Phase one of this study used chloride salt replacements calculated as equivalent ionic strengths to those of sodium chloride (2.5%). Phase two consisted of sodium chloride replacement levels of 0%, 25%, 50%, 75% and 100% with a 70:30 mixture of magnesium chloride and potassium chloride, respectively. These ratios were not based on equivalent ionic strengths to sodium chloride as was the case in phase one. In both phases, all samples except control (meat only) contained the following ingredients: 3% added ice and 41.62 g of seasoning (34.1% sage, 31.8% black pepper, 21.1% cane sugar, 6.8% monosodium glutamate and 6.2% cracked red pepper). Duplicate (100 g) samples were: mixed with dry ingredients, stuffed into 36 mm collagen casings, tied with string at both ends of the links, packaged in foam trays and wrapped with polyvinyl chloride film. Packaged links were stored in a retail case (0-3^{o}C, 60 ft candles of incandescent lighting, 10 hr/day) for a period of 12 days. Links were then removed from the case and the following determinations were made: pH (Acton et al., 1972), total aerobic plate counts (AOAC, 1975) and Trichinella spiralis viability (Zimmermann et al., 1961). In addition, cooked juice loss (Wierbicki et al., 1957b) was performed on linked sausage prepared in phase two.

In experiment two, effects of curing, heating and freezing on trichinae viability in hams were studied. In phase one of the second experi-

ment, 36 paired hams were allotted into two groups. The first group (18 right hams) was divided into three categories and processed according to the design shown in Table 1. Pickle formulations for pumped hams are shown in Table 2. These hams were placed in cover pickles (3°C) for four days. The second group of hams (18 left hams) was not pumped and was sampled immediately for viable trichinae (control). Those hams that were pumped and either heated or not heated (18 right hams) were sampled after their respective treatments. Muscle samples were examined for trichinae viability according to procedures described by Zimmermann et al. (1961). Phase two of the second experiment involved freezing of uncooked-pumped hams and raw-unpumped (green) hams. The experimental design for this phase of the study appears in Table 3. Six green hams and nine treated hams were frozen (-29°C). All treated hams and three randomly selected green hams were sampled daily until no viable trichinae were detected. Phase two of this study was designed to determine the effects of pumping ingredients on the destruction of trichinae during freezing and storage.

Data from both experiments were analyzed by analysis of variance (Steel and Torrie, 1960) and mean separation (Duncan, 1955). Data from phase one of the second experiment were analyzed by paired-t distribution (Li, 1957).

Table 1--Experimental design for trichinae-infected hams

Curing ingredient[a] level		Treatment		
NaCl(%)	NO_2(ppm)	Not pumped (Control)	Pumped, not heated	Pumped, heated to 43.3°C
0	0	3L[b]	---------->	3R[b]
		3L	----------	----------> 3R
1.6	120	3L	---------->	3R
		3L	----------	----------> 3R
2.6	156	3L	---------->	3R
		3L	----------	----------> 3R

[a]NaCl level based on calculated percentage in finished product; NO_2 level based on ppm in-going into pickle for a 10% pump.

[b]L=left hams, R=right hams.

Table 2--Pickle formulations for trichinae-infected hams[a]

Ingredient	Percentage of ingredients according to treatments[b]		
	0% NaCl-0 ppm NO_2	1.6% NaCl-120 ppm NO_2	2.6% NaCl-156 ppm NO_2
Water	99.26	97.75	96.85
Salt (NaCl)	---	1.5	2.4
Dextrose	.45	.45	.45
Sodium tripolyphosphate	.23	.23	.23
Sodium erythorbate	.055	.055	.055
Sodium nitrite ($NaNO_2$)	---	.012	.0156
Total	100%	100%	100%

[a]Hams were pumped with appropriate formulation and placed in cover pickle (4 da). Cover pickles were identical to those used for pumping except that sodium tripolyphosphate was omitted.

[b]One-half (n=9) of all pumped hams was heated to 43.3°C; the other half was not heated. NaCl level based on calculated percentage in finished product; NO_2 level based on ppm ingoing into pickle for a 10% pump.

Table 3--Experimental design for freezing and storage (-29°C) of trichinae-infected hams[a]

Sampling period (days)	Treatments			
	Not pumped or heated	Pumped-not heated		
		0% NaCl-0 ppm NO_2	1.6% NaCl-120 ppm NO_2	2.6% NaCl-156 ppm NO_2
1	3	3	3	3
2	3	3	3	3
3	3	3	3	3
4	3	3	3	3
5	3	3	3	3
6	3	3	3	3
7	3	3	3	3
8	3	3	3	3

[a]Three hams from each treatment were sampled daily until no viable trichinae were detected. All hams did not exceed 15.2 cm in thickness.

CHAPTER IV

EFFECTS OF CHLORIDE SALTS AND SODIUM NITRITE ON VIABILITY OF *TRICHINELLA SPIRALIS* AND OTHER PROPERTIES OF PORK SAUSAGE (EXPERIMENT 1)

Introduction

Current U.S. food regulatory policy is directed toward the safety and stability of foods. Recent concern about sodium intake in the North American diet has suggested reduction of and labeling of foods containing sodium (FDA, USDA, FTC, 1979). Use of chloride salts in processed meats has been studied as an alternative to dietary sodium (Terrell, 1981). However, functions of salt substitutes and their effects on physical properties of processed meats is not fully understood. Incorporation of sodium nitrite into processed meat products serves to enhance flavor and develop cured meat color (Terrell, 1980). However, its effect upon trichinae viability in pork is not fully understood. Accordingly, the present study determined the effect of four different chloride salts and two levels of sodium nitrite on aerobic plate counts, cooked juice loss and viability of *T. spiralis* in pork sausage.

Experimental

Four pork shoulders infected with *Trichinella spiralis* were obtained from the USDA Meat Science Research Laboratory (Beltsville, MD). These shoulders, which averaged 70 to 80 larvae per gram of tissue, were used in two experiments. In the first experiment, pork shoulders were boned and ground through a 1.25 cm plate. Triplicate (100 g) samples of ground

pork were then assigned to the following treatments: sodium nitrite levels (ppm of raw meat weight) of 0, 75 or 150 ppm and chloride salt levels (percentage of raw meat weight) of 2.5% sodium, 3.18% potassium, 1.35% magnesium or 1.58% calcium. Addition of chloride salts was based on ionic strengths equivalent to 2.5% sodium chloride and were calculated using the formula $\mu=1/2\Sigma c_i z_i^2$ where μ=ionic strength, c_i=concentration and z_i=the charge of the ion. Meat only controls were made for each treatment combiation to determine base numbers of trichinae larvae.

In an attempt to simulate manufacturing conditions, a second experiment was conducted in which ionic strength equivalency was not considered. Replacement of sodium chloride with a mixture containing 70% magnesium chloride and 30% potassium chloride was done on a weight-percentage basis at the following percentages: 0, 25, 50, 75 or 100%. In both experiments, all samples except controls (meat only) contained 3% ice and 41.62 g of seasoning (34.1% sage, 31.8% black pepper, 21.1% cane sugar, 6.8% monosodium glutamate and 6.2% cracked red pepper). Duplicate 100 g samples were mixed with dry ingredients, stuffed into 36 mm collagen casings, tied with string at both ends of the links, packaged in foam trays and wrapped with polyvinyl chloride film. Packaged links were stored in a retail case (0-3°C, 60 ft candles of incandescent lighting, 10 hr/day) for a period of 12 days.

Identification of viable trichinae larvae was determined according to a modification of the procedure used by Zimmermann et al. (1960). In the first study, 10 g of sausage was used; in the second study, 33.8 g was used. Appropriate sausage samples (10 or 33.8 g) were blended (90 sec in a Waring Blendor) in a 200 ml solution of 2.0% pepsin and 1.2%

concentrated HCl. Samples were transferred to glass jars, capped, labeled and stored overnight in an incubator (37°C). Samples were removed (18-24 hr) from the incubator and prepared for analysis of trichinae. The supernant was decanted through a No. 40 seive into a 1000 ml graduated cylinder. Additional warm water (25-35°C) was added to bring the solution to volume. After 15 minutes, the top 600 ml of the solution was siphoned off. Three ml of the bottom layer was transferred (via micropipette) into a sectioned counting chamber and observed with a dissecting microscope (30X). Larvae considered viable were those which were motile, tightly coiled and light brown in color. Larvae which were considered dead were either straight or shaped as the number 6, clear in color, void of movement and sometime fragmented.

Data were analyzed by analysis of variance (Steel and Torrie, 1960) and mean separation (Duncan, 1955).

Results and Discussion

Mean pH values according to chloride salt and nitrite levels are shown in Table 4. Addition of 75 or 150 ppm of sodium nitrite had no effect ($P>0.05$) on pH of sausages, regardless of chloride salt used. Use of 1.35% magnesium chloride or 1.58% calcium chloride decreased ($P<0.05$) pH values in comparison to those for sausages made with either sodium or potassium chloride (order of means). When compared to controls, use of chloride salts decreased ($P<0.05$) pH values of linked pork sausages in 11 of 12 treatment combinations.

Mean aerobic plate counts according to chloride salt and nitrite level are presented in Table 5. Within chloride salt treatments, addi-

Table 4--Mean pH values of linked pork sausage according to treatment combination (12 da display case storage)

Sodium nitrite (ppm)[b]	Chloride salt[a] 2.5% sodium chloride (A)	3.18% potassium chloride (B)	1.35% magnesium chloride (C)	1.58% calcium chloride (D)	Order of means[c]
0	6.15[e]	6.23[de]	5.47[e]	5.33[e]	B A C D
75	6.02[e]	6.00[e]	5.48[e]	5.47[e]	A B C D
150	6.08[e]	6.07[e]	5.62[e]	5.41[e]	A B C D
Control (meat only)	6.64[d]	6.60[d]	6.83[d]	6.48[d]	C A B D

[a]Ionic strength equivalent to 2.5% NaCl.

[b]Parts per million (ppm) based on raw meat weight.

[c]Means underscored by the same line are not different (P>0.05).

[de]Means within a column followed by a common superscript letter are not different (P>0.05).

Table 5--Mean aerobic plate count (Log) of linked pork sausage according to treatment combination (12 da display case storage).

Sodium nitrite (ppm)[b]	Chloride salt[a]: 2.5% sodium chloride (A)	3.18% potassium chloride (B)	1.35% magnesium chloride (C)	1.58% calcium chloride (D)	Order of means[c]
0	6.30[e]	7.23[e]	7.00[d]	5.91[e]	B C A D
75	6.18[e]	6.77[e]	7.72[d]	5.61[e]	C B A D
150	6.46[e]	6.76[e]	7.34[d]	5.70[e]	C B A D
Control (meat only)	8.76[d]	8.87[d]	8.43[d]	8.80[d]	B D A C

[a]Ionic strength equivalent to 2.5% NaCl.

[b]Parts per million (ppm) based on raw meat weight.

[c]Means underscored by the same line are not different (P>0.05).

[de]Means within a column followed by a common superscript letter are not different (P>0.05).

tion of 75 or 150 ppm sodium nitrite did not lower plate counts ($P>0.05$). However, within nitrite levels (75 and 150 ppm NO_2), linked sausages made with calcium chloride or sodium chloride of equivalent ionic strengths had lower counts than links made with magnesium chloride.

Percentages of dead trichinae larvae according to chloride salt and nitrite levels are shown in Table 6. Addition of 75 or 150 ppm sodium nitrite had no effect on percentages of dead trichinae, regardless of chloride salt. Percentages of dead trichinae larvae were greater for potassium chloride (97.4%) and sodium chloride (83.5%) than for magnesium chloride (37.8%) or calcium chloride (57.7%) when 0 or 150 ppm sodium nitrite was added to linked pork sausages. The highest numerical larvae death loss occurred in sausages made with potassium chloride. However, this percentage was not different ($P>0.05$) from that for sausages made with sodium chloride. Addition of sodium chloride, potassium chloride and calcium chloride increased ($P<0.05$) larvae death percentages when compared to controls.

Data from the second experiment in which certain percentages of sodium chloride were replaced with a mixture containing 70% magnesium chloride and 30% potassium chloride are shown in Table 7. Values for pH and cooked juice loss were not affected ($P>0.05$) by any of the sodium chloride replacement levels (0, 25, 50, 75 or 100%). Although not significant ($P>0.05$), percentages of dead trichinae larvae numerically increased from 9.0 (control) to 20.2% when sodium chloride was added (0% replacement). Replacement of 25 and 50% of the sodium chloride resulted in a numerical increase in the trichinae larvae death percentage, but this increase was not different ($P>0.05$) from controls.

Table 6—Mean percentages of dead trichinae in linked pork sausage according to treatment combination (12 da display case storage)

Sodium nitrite (ppm)[b]	Chloride salt[a] 2.5% sodium chloride (A)	3.18% potassium chloride (B)	1.35% magnesium chloride (C)	1.58% calcium chloride (D)	Order of means[c]
0	85.3[d]	97.8[d]	41.6[d]	51.9[d]	B A D C
75	80.7[d]	97.2[d]	35.8[d]	67.6[d]	B A D C
150	84.5[d]	97.1[d]	36.0[d]	53.0[d]	B A D C
Control (meat only)	20.4[e]	27.3[e]	28.7[d]	15.3[e]	C B A D

[a]Ionic strength equivalent to 2.5% NaCl.

[b]Parts per million (ppm) based on raw meat weight.

[c]Means underscored by the same line are not different (P>0.05).

[de]Means within a column followed by a common superscript letter are not different (P>0.05).

Table 7--Mean pH, aerobic plate count, percentages of dead trichinae and cooked juice loss of linked pork sausage according to sodium chloride replacement level (12 da display case storage)

Percentage NaCl replacement	pH	Aerobic plate count[b]	Percentage dead trichinae	Cooked juice loss (%)
0	5.62[c]	7.53[d]	20.2[de]	24.5[c]
25	5.62[c]	7.97[c]	21.0[de]	24.2[c]
50	5.68[c]	8.01[c]	25.4[cde]	21.6[c]
75	5.58[c]	7.99[c]	35.5[cd]	18.8[c]
100	5.63[c]	7.96[c]	40.9[c]	22.4[c]
Control (Meat only)	5.96[d]	8.11[c]	9.0[e]	22.4[c]

[a]Replacement of 2.5% sodium chloride with 70% $MgCl_2$: 30% KCl. Replacement was not based on ionic strengths equivalent to 2.5% NaCl.

[b]Log aerobic plate count.

[cde]Means within a column followed by a common superscript letter are not different (P>0.05).

However, linked pork sausages in which 100% of the sodium chloride had been replaced had greater ($P<0.05$) percentages of dead trichinae than those sausages with 100% sodium chloride (0% replacement). Aerobic plate counts for controls were not different ($P>0.05$) from those of sausages in which 25, 50, 75 or 100% of the sodium chloride was replaced. However, those links containing 100% sodium chloride (0% replacement) had lower aerobic plate counts when compared to all other sausages.

Effects of various chloride salts on pH and cooked juice loss of beef clod muscles have been reported (Terrell et al., 1981). Data from this study (Table 4) agree with that of the previous study in that pH values are lowered when equivalent ionic strengths of magnesium chloride and calcium chloride are added to meat. Although magnesium chloride lowered pH in linked sausages, it had no apparent effect on total plate counts (Table 5). These results reiterate the conclusion by Terrell et al. (1981) that pH values are not closely associated with total plate counts or with cooked juice loss in formulated meat products. Since additions of 75 or 150 ppm sodium nitrite did not reduce aerobic plate counts (Table 5), there is no need to add $NaNO_2$ to sausages containing these levels of chloride salts. However, inclusion of equivalent ionic strengths of sodium chloride and calcium chloride significantly reduced these counts. These results suggest that reductions in aerobic plate counts may be more closely associated with specific effects from different ions than from effects due to pH or nitrite level.

Pigs infected with 50,000 trichinae larvae and slaughtered 63 days post-infection produced Boston butts and picnic shoulders with 297 and 504 larvae per gram of muscle, respectively (Zimmermann, 1970). In the

present study there were about 40 larvae/ml in phase one and 109 larvae/ml in phase two. Since no chemical is known to destroy trichinae in vivo (Otto and Abrams, 1939), most research has determined the effects of heating, freezing and/or sodium chloride concentrations on survival of trichinae (Rust and Zimmermann, 1972; Gammon et al., 1968; Zimmermann, 1971). The following conclusions were made from these previous studies: (a) heating to 58.3°C or freezing pork for sufficient time periods and (b) maintaining a brine (sodium chloride) content of at least 8%, are sufficient to provide an adequate margin of safety for trichinae. In the present study (Table 6), use of potassium chloride resulted in trichinae larvae destruction of greater than 97%. Potassium chloride proved to be more effective in destroying trichinae than was magnesium chloride or calcium chloride. Hence, it is possible that there are sodium chloride substitutes that would meet functional criteria for processed meat products. However, FDA approval and, more importantly, USDA-FSQS approval and labeling of processed meats containing KCl has not been established (Terrell and Olson, 1981).

Summary and Conclusions

In summary, the use of chloride salts numerically reduced total plate counts compared to controls (no added salts). However, addition of sodium nitrite (75 or 150 ppm) did not affect total plate counts. Percentages of dead trichinae larvae were greater ($P<0.05$) for potassium chloride than for magnesium chloride or calcium chloride. However, in the second study when salts of equivalent ionic strengths were not used, replacement of sodium chloride with a 70:30 mixture of magnesium chloride

and potassium chloride, respectively, did not affect (increase or decrease) pH values, aerobic plate count or juice loss during cooking. Percentages of dead trichinae larvae increased for the 75 and 100% replacement levels when compared to controls.

CHAPTER V

EFFECTS OF PICKLE INGREDIENTS AND HEATING AND FREEZING ON TRICHINAE SURVIVAL IN HAMS (EXPERIMENT 2)

Introduction

Research by Ransom (1916), Ransom and Schwartz (1919) and Ransom et al. (1920) serves as the basis for federal regulations governing treatment of pork for destruction of viable trichinae. From this research it was concluded that the following conditions were effective in destroying viable trichinae: (1) 3.3 lb of salt per 100 lb of meat followed by a specified drying period, (2) freezing at a specified temperature for a given length of time and (3) heating gradually to an internal product temperature of 58.3°C. However, the interaction of pickle curing ingredients (salt and nitrite) and heat upon trichinae viability remains unclear. In addition, effects of freezing cured-unheated hams, with respect to survival of trichinae, remains vague. Accordingly, the present study determined effects of curing compounds (NaCl and $NaNO_2$) and heating and freezing on trichinae viability in hams.

Experimental

Forty-eight hams, infected with Trichinella spiralis, were obtained from the USDA Meat Science Research Laboratory (Beltsville, Maryland). These hams, which contained an average of three to 12 larvae per gram of tissue, were used in two experiments. In the first experiment (phase one) 36 paired hams were allotted into two groups. The first group (18 right hams) was divided into three categories and processed according to the

design shown in Table 1. Pickle formulations for pumped hams are shown in Table 2. These hams were placed in cover pickles for four days at 3°C. The second group (18 left hams) was not pumped and was sampled immediately (controls) whereas those that were pumped and either heated or not heated (18 right hams) were sampled after their respective treatments. The heat process schedule used for heated hams (n=nine, right hams) is shown in Table 8. Muscle samples were examined for trichinae viability according to procedures described by Zimmermann et al. (1961) and outlined previously in Chapter IV.

In phase two of this experiment, effects of freezing bone-in hams on trichinae were studied. Hams (n=15) were assigned to one of four categories and processed according to the design shown in Table 3. Nine of the 15 hams were separated into three groups (n=3 each) and pumped with solutions containing either 0% NaCl-0 ppm NO_2 or 1.6% NaCl-120 ppm NO_2 or 2.6% NaCl-156 ppm NO_2. Sodium chloride percentages were based on theoretical levels in finished cured hams whereas nitrite levels were based on in-going levels into pickle for a 10% pump. The 1.6% NaCl-120 ppm NO_2 combination was selected to represent commercial practice for pumped bacon; the 2.6% NaCl-156 ppm NO_2 was selected as that typical of commercial hams. All pumping treatments contained 550 ppm sodium erythorbate and all hams were placed in cover pickle (4 da at 3°C). The remaining green hams (raw-not pumped, n=6) served as controls and were used to determine base levels of viable trichinae.

All cured hams plus controls were wrapped with polyvinyl chloride film, placed in cardboard boxes and frozen and stored at -29°C. Muscle samples were obtained daily by removing two, 1.27 cm slices from the butt

Table 8--Heat process schedule for pumped hams[a]

Time (hr)	Dry bulb	Wet bulb	Relative humidity (%)	Damper
2	62.7°C	0	---	open
1	68.3°C	0	---	closed
2	73.9°C	56.6°C	41	closed
2	79.4°C	62.2°C	42	closed
1.5	85.0°C	68.8°C	48	closed

[a]Hams were heated to an internal temperature of 43.3°C.

face. The exterior slice was discarded while the center of the interior slice was saved for subsequent analysis. Samples were examined for viable trichinae according to the procedure outlined in Chapter IV. Examination of hams at one-day intervals continued until no viable trichinae were detected. Data from both experiments were analyzed by analysis of variance (Steel and Torrie, 1960) and mean separation (Duncan, 1955). Data from the first experiment were also analyzed by paired-t distribution (Li, 1957).

Results and Discussion

Analysis of variance F values for hams that were pumped and heated are shown in Table 9. Interactions (temperature x pumping ingredients) for the three traits included in Table 9 were not significant; pumping ingredients affected heating shrinkage ($P<0.001$) and cooler shrinkage ($P<0.01$) whereas temperature affected percentages of dead trichinae ($P<0.001$) and cooler shrinkage ($P<0.01$).

Table 10 shows mean values for percentage of dead trichinae, heating shrinkage and cooler shrinkage and the paired-t analysis of viable trichinae according to treatment combinations. With the exception of hams with 0% NaCl-0 ppm NO_2 that were not heated, hams heated to 43.3°C had fewer viable trichinae than those that were not heated ($P<0.05$). Although not statistically different among treatments within the heated hams, those with curing ingredients of 2.6% NaCl-156 ppm NO_2 had greater death loss percentages than those hams with 1.6% NaCl-120 ppm NO_2 and 0% NaCl-0 ppm NO_2. Heating and cooler shrinkage values were lower ($P<0.05$) for heated hams cured with 2.6% NaCl-156 ppm NO_2 than for not heated hams with 0%

Table 9--Analysis of variance F values for pumped hams

Source of variation	Degrees of freedom	Percentage dead trichinae	Heating shrinkage (%)	Cooler shrinkage (%)
Temperature[a]	1	41.3***		16.8**
Pumping ingredients[b]	2	1.2	44.8***	7.6**
Temperature x pumping ingredients	2	1.9		0.2

[a]One-half of all hams (n=9) were heated to 43.3°C. The other one-half (n=9) were refrigerated at 3°C.

[b]Salt and nitrite levels: 0% NaCl-0 ppm NO_2; 1.6% NaCl-120 ppm NO_2; 2.6% NaCl-156 ppm NO_2.

**P<0.01
***P<0.001

Table 10--Mean percentages of dead trichinae, heating shrinkage and cooler shrinkage and level of probability for viable trichinae according to treatment combination

Treatment combination	Dead trichinae (%)	Heating shrinkage (%)	Cooler shrinkage (%)	Viable trichinae/gr[a]		
				Right hams (treatment combination)	Left hams (raw)	Level of probability[c]
Not heated						
0% NaCl-0 ppm $NaNO_2$	33.7^{de}	---	3.8^{f}	4.1	8.1	0.11
1.6% NaCl-120 ppm $NaNO_2$	12.9^{d}	---	2.8^{ef}	6.8	4.7	0.49
2.6% NaCl-156 ppm $NaNO_2$	32.3^{d}	---	2.6^{ef}	5.3	6.7	0.43
Heated[b]						
0% NaCl-0 ppm $NaNO_2$	63.8^{ef}	11.8^{d}	2.7^{ef}	2.4	6.4	0.23
1.6% NaCl-120 ppm $NaNO_2$	80.1^{f}	6.1^{f}	1.5^{de}	1.2	7.5	0.12
2.6% NaCl-156 ppm $NaNO_2$	88.6^{f}	8.7^{e}	1.0^{d}	0.4	6.0	0.04

[a]Internal ham samples were removed from the biceps femoris and semimembranosus muscles and examined. Raw ham values for trichinae were considered to be base level and were compared to treated counterparts.

[b]Heated to an internal product temperature of 43.3°C.

[c]Probability that the difference between treatments was statistically significant as determined by paired-t distribution.

[def]Means bearing a common superscript letter are not different (P>0.05).

NaCl-0 ppm NO_2. However, among hams that were not heated, there was no difference ($P>0.05$) among treatment combinations for cooler shrinkage.

These data suggest that injection of raw hams with either 1.6% NaCl-120 ppm NO_2 or 2.6% NaCl-156 ppm NO_2 had no effect on reducing viable trichinae larvae. However, heating of hams pumped with salt and nitrite levels similar to those used in commericial practice significantly ($P<0.05$) reduced the numbers of viable trichinae. In heated hams, addition of 2.6% NaCl-156 ppm NO_2 reduced both heating and cooler shrinkage values compared to hams with 0% NaCl-0 ppm NO_2.

Left hams were not pumped or heated and were used to establish base levels of viable trichinae. However, right hams received treatment combinations as shown in Table 1. Because these were paired hams, "t" tests of viable trichinae per gram of muscle were conducted and these data are shown in Table 10. Left hams (control) averaged 4.7 to 8.1 larvae per gram of tissue, whereas those receiving pumping ingredients and either heated or not heated averaged 0.4 to 6.8 viable trichinae larvae per gram of muscle. However, the only significant difference for viable trichinae per gram of muscle was in heated hams that contained 2.6% NaCl-156 ppm NO_2. These paired-t values (Table 10) compared to analysis of variance F values for pumped hams (Table 9) suggest that pumping hams with pumping ingredients of 0% NaCl-0 ppm NO_2, 1.6% NaCl-120 ppm NO_2 and 2.6% NaCl-156 ppm NO_2 in raw, not heated hams and that use of pumping ingredients of 0% NaCl-0 ppm NO_2 and 1.6% NaCl-120 ppm NO_2 in heated hams does not significantly reduce numbers of viable trichinae.

Previous research (Ransom et al., 1920; Allen and Goldberg, 1962; Gammon et al., 1968; Crouse and Kemp, 1969; Zimmermann, 1971) suggests

that addition of salt to pork followed by a storage period is effective in killing trichinae. In addition, research (Ransom and Schwartz, 1919; Otto and Abrams, 1939; Carlin et al., 1969) has shown that heating to a minimum temperature of 58.8°C kills viable trichinae. Since the addition of NaCl and NO_2 to unheated hams or to heated hams did not destroy trichinae, a higher level of NaCl than that used in the present study may be required in order to kill viable trichinae.

Mean percentages of dead trichinae in frozen and stored hams are shown in Table 11. There were no differences in these percentages among all treatments, including controls, after one day of storage. After two days of storage, hams that were not pumped had significantly ($P<0.05$) greater death percentages than those hams that were pumped, regardless of ingredient combinations used in the pumping pickle. However, after three days of storage, hams that were pumped with 0% NaCl-0 ppm NO_2 had greater percentages of death loss than hams pumped with 2.6% NaCl-156 ppm NO_2; there were no differences among other treatment comparisons at this same storage period. A similar trend for these differences was observed after four days of storage, but at this period, hams pumped with 2.6% NaCl-156 ppm NO_2 had lower death loss percentages than controls. There were no differences among treatments including controls from the fifth day of storage through the eighth day of storage. These comparisons of treatments within each storage period suggest that regardless of pickle ingredients and pumping of hams, a storage period of five days at -29°C was effective in achieving death loss percentages statistically equivalent to those of controls. However, pumping hams with 2.6% NaCl-156 ppm NO_2 and storage at -29°C for three or four days resulted in numerically

Table 11--Mean percentages of dead trichinae from frozen and stored hams (-29°C)[a]

Sampling period (days)	Not pumped (A)	Pumped 0% NaCl/ 0 ppm NO_2 (B)	Pumped 1.6% NaCl/ 120 ppm NO_2 (C)	Pumped 2.6% NaCl/ 156 ppm NO_2 (D)	Order of Means[b]
1	24.7^{c}	37.2^{c}	28.9^{c}	34.1^{c}	B D C A
2	58.9^{d}	30.9^{c}	26.7^{c}	38.7^{c}	A D B C
3	85.1^{e}	91.2^{d}	84.8^{d}	75.3^{d}	B A C D
4	98.1^{f}	96.6^{d}	89.7^{de}	84.1^{de}	A B C D
5	99.7^{f}	99.2^{d}	96.1^{ef}	90.3^{ef}	A B C D
6	100.0^{f}	99.8^{d}	98.1^{ef}	93.6^{ef}	A B C D
7	100.0^{f}	100.0^{d}	99.7^{f}	98.6^{ef}	A B C D
8	100.0^{f}	100.0^{d}	100.0^{f}	100.0^{f}	A B C D

[a]Three hams from each treatment were sampled daily; hams did not exceed 15.3 cm in thickness.

[b]Means underscored by the same line are not different (P>0.05).

[cdef]Means within a column followed by a common superscript letter are not different (P>0.05).

lower death loss values than for all other treatments, including controls. Although the latter comparison (three or four day period) of death loss percentages was not significant among all comparisons, it does indicate that higher levels of salt and nitrite (1.6% NaCl-120 ppm NO_2 and 2.6% NaCl-156 ppm NO_2) are not as effective as other treatments in destroying trichinae.

Trichinae death loss percentages within treatments and over all storage periods (Table 11) suggest that in order to achieve a death loss of 100%, raw hams less than 15.3 cm in thickness that were frozen and stored at -29°C required six days. Raw hams that were pumped with 0% NaCl-0 ppm NO_2, 1.6% NaCl-120 ppm NO_2 and 2.6% NaCl-156 ppm NO_2 required seven, eight and eight days, respectively, to achieve this same percentage. However, controls achieved statistically equivalent percentages to those of 100% after four days of storage, whereas hams pumped with either combination of salt and nitrite required five days to achieve this same equivalency. Numerical data suggest that rates for achieving 100% death loss equivalency of trichinae are not enhanced by pumping of hams with these levels of salt and nitrite and that pumping of hams with any combination of pickle ingredients is not as effective in destroying trichinae as is freezing and storage of raw hams (not pumped).

There is evidence (Ransom and Schwartz, 1919) that the addition of saline solutions (physiological or at low levels of 1-3%) may enhance the survival of trichinae (e.g., decrease death loss). On the other hand, it is known (Ransom et al., 1920) that relatively high concentrations of sodium chloride (brine content) are an extremely effective method of destroying trichinae.

Although data from the present study were quite variable and may not be used as conclusive evidence that pumping hams with solutions of curing ingredients prolongs survival of trichinae during frozen storage at -29°C, the risk that some larvae may survive such treatment, as judged by the author, is too great to recommend this as a commercial practice. Further, the current study was not designed to determine effects of sodium nitrite on survival of trichinae but the data suggest that combinations of nitrite and low levels of salt may not be an effective method of destroying trichinae. These events may be hypothesized as follows: (a) loss of free moisture via dehydration or by freezing pork to an internal temperature of about -29°C, (b) a decrease in water activity (a_w) and (c) for pork that contains sodium chloride, a corresponding increase in brine content (sodium chloride salt concentration in the aqueous phase).

Summary and Conclusions

In summary, the use of heat on bone-in hams significantly increased death losses of trichinae. The use of pumping ingredients affected cooler shrinkage and heating shrinkage; interactions (temperature x curing ingredients) were not significant for these traits. Although right (treated) hams generally had lower numbers of viable trichinae compared to left hams (controls), the heated hams with 2.6% NaCl-156 ppm NO_2 was the only group that had different viable trichinae numbers from its paired control when analyzed by paired-t distribution.

Hams that were pumped and frozen and stored at -29°C required longer storage periods than controls (raw, not pumped) in order to be free of viable trichinae. Controls were free of viable trichinae after six days

of storage whereas hams with 0% NaCl-0 ppm NO_2 required seven days and hams with 1.6% NaCl-120 ppm NO_2 and 2.6% NaCl-156 ppm NO_2 required eight days to achieve 100% death of trichinae larvae.

CHAPTER VI

GENERAL SUMMARY AND CONCLUSIONS

On the basis of these studies it is concluded that:

(a) Use of chloride salts numerically reduced total plate counts of linked sausage compared to controls (no added salts).

(b) Addition of sodium nitrite (75 or 150 ppm) to sausages containing equivalent ionic strengths of various chloride salts (NaCl, KCl, $MgCl_2$ or $CaCl_2$) did not affect pH, aerobic plate counts or percentages of dead trichinae when compared to those sausages made without sodium nitrite.

(c) Use of potassium chloride or sodium chloride in linked pork sausage resulted in greater death losses of trichinae compared to magnesium chloride or calcium chloride when 0 or 150 ppm $NaNO_2$ was added.

(d) Values for pH and cooked juice loss were not affected in linked pork sausage in which certain percentages of sodium chloride were replaced with 70% magnesium chloride and 30% potassium chloride.

(e) Percentages of dead trichinae larvae increased when 100% of sodium chloride was replaced with a mixture of magnesium chloride and potassium chloride as compared to that when 0 or 25% of the sodium chloride was replaced.

(f) Aerobic plate counts for controls (meat only) were not different from those sausages in which 25, 50, 75 or 100% of the sodium chloride was replaced.

(g) Links containing sodium chloride (0% replacement) had lower aerobic plate counts when compared to all other sausages.

(h) The use of heat on bone-in hams significantly increased death losses of trichinae. The use of pumping ingredients affected cooler shrinkage and heating shrinkage. Interactions (temperature x pumping ingredients) were not significant for these same traits.

(i) The group of hams pumped with 2.6% NaCl-156 ppm NO_2 and then heated was the only group that was significantly different in numbers of viable trichinae from its paired control when analyzed by paired-t distribution.

(j) For green hams (raw, not pumped, less than 15.3 cm in thickness) that were frozen and stored at -29°C, six days were required to kill all trichinae. For raw hams pumped with 0% NaCl-0 ppm NO_2, seven days of frozen storage were needed to kill all trichinae; for raw hams pumped with either 1.6% NaCl-120 ppm NO_2 or 2.6% NaCl-156 ppm NO_2, eight days were required to kill all trichinae.

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