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F. A. Draughon

F. A. Draughon, Major Professor

We have read this thesis
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H. Darght Lunday

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SHELFLIFE OF PROCESSED TURKEY AND THE
SURVIVAL OF SALMONELLA IN TURKEY HAM
HELD UNDER VACUUM AND AEROBIC
ATMOSPHERES

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ABSTRACT

The survival of three strains of Salmonella, S. blockley, S. infantis, and S. typhimurium, in vacuum and aerobically packaged turkey hams stored at 4°C for 15 days was studied. Hams were formulated with selected levels of salt in 0.5% increments (0.5-3.0%), erythorbate (0 and 550 ppm), sodium tripolyphosphate (STPP) (0 and 0.5%), and one level of nitrite (156 ppm). Aerobic, lactic acid, and psychrotrophic bacteria were enumerated to evaluate the effects of formulation and packaging of turkey ham on their survival during refrigerated storage. TBA, nitrite and pH were analyzed to monitor the chemical changes in turkey hams due to the different formulation and storage.

Salmonella declined the greatest in highest salt levels (2.5-3.0%) under vacuum packaging and in lowest salt level (0.5%) with the addition of erythorbate and STPP under aerobic packaging. The inhibitory effects of erythorbate and STPP were found in hams formulated with lower salt levels (0.5-1.5%) under aerobic packaging. Survival of Salmonella was significantly ($p < 0.05$) greater in vacuum storage than in aerobic storage. Aerobic, lactic acid, and psychrotrophic bacteria grew more rapidly in aerobically packaged turkey hams than in vacuum packaged hams, thereby reducing shelflife of the product. Inhibition of

Salmonella, aerobes, lactobacilli, and/or psychrotrophs was mainly attributed to the salt in turkey hams. Erythorbate and STPP significantly ($p < 0.05$) reduced TBA values in vacuum and aerobically packaged turkey hams stored at 4°C for 15 days.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION.....	1
II. LITERATURE REVIEW.....	4
III. MATERIALS AND METHODS.....	12
1. Ham Manufacture and Sample Preparation.....	12
2. Sample Inoculation and Packaging.....	14
3. Microbiological Analysis.....	15
A. <u>Salmonella</u> enumeration.....	15
B. Total microbial counts.....	17
4. Compositional Analyses.....	17
5. Nitrite and TBA Analyses.....	18
6. Salt Analysis.....	19
7. pH and Titratable Acidity.....	20
8. Statistical Analyses.....	21
IV. RESULTS AND DISCUSSION.....	22
1. Proximate Analyses.....	22
2. pH and Titratable Acidity.....	26
3. Lipid Oxidation.....	30
4. Nitrite.....	32
5. <u>Salmonella</u>	36
6. Aerobes, Lactobacilli, and Psychrotrophs	46
V. CONCLUSION.....	56
LIST OF REFERENCES.....	57
APPENDIX.....	66
VITA.....	81

LIST OF TABLES

TABLE		PAGE
1.	Comparison of physiological characteristics of salmonellae and the relevant properties of cooked cured meat.....	3
2.	Formulation of turkey hams.....	13
3.	Proximate composition of turkey hams prepared with six salt levels, erythorbate, nitrite, and STPP, alone and in combination.....	23
4.	Main effects on proximate composition in turkey hams formulated with selected levels of salt, erythorbate, and STPP.....	24
5.	Slopes of pH and titratable acidity for turkey hams packaged under vacuum or aerobic conditions and held at 4°C.....	28
6.	Mean changes of pH and TA (slope) by treatment in turkey hams held under vacuum and aerobic atmospheres at 4°C for 15 days.....	29
7.	Main effects on TBA values of turkey hams formulated with selected levels of salt, erythorbate, and STPP.....	31
8.	Initial and final concentration ^A (ppm) of nitrite in vacuum and aerobically packaged turkey hams.....	33
9.	Mean residual nitrite by main treatment effect in turkey hams held at 4°C for 15 days.....	34

LIST OF TABLES (Continued)

TABLE	PAGE
10. Main effects of selected levels of salt, erythorbate, STPP on mean slopes of survival curves of <u>Salmonella</u> in vacuum and aerobically packaged turkey hams stored at 4°C for 15 days..	41
11. Mean slopes of three strains of <u>Salmonella</u> in aerobically packaged turkey hams held at 4°C....	43
12. Mean slopes of survival curves from three strains of <u>Salmonella</u> in vacuum packaged turkey hams held at 4°C.....	44
13. Main effects of selected levels of salt, erythorbate, STPP on aerobes, lactobacilli, and psychrotrophs in vacuum and aerobically packaged turkey hams stored at 4°C for 0 to 15 days.....	55
A.1. ANOVA table on main effects for protein composition in turkey hams.....	67
A.2. ANOVA table on main effects for fat composition in turkey hams.....	67
A.3. ANOVA table on main effects for moisture composition in turkey hams.....	68
A.4. ANOVA table on main effects for ash composition in turkey hams.....	68
A.5. ANOVA table on main effects for TBA analysis on turkey hams.....	69
A.6. ANOVA table on main effects for TA analysis on vacuum packaged turkey hams.....	69

LIST OF TABLES (Continued)

TABLE	PAGE
A.7. ANOVA table on main effects for TA analysis on aerobically packaged turkey hams.....	70
A.8. ANOVA table on atmosphere effect for TA analysis on turkey hams.....	70
A.9. ANOVA table on main effects for pH analysis on vacuum packaged turkey hams.....	71
A.10. ANOVA table on main effects for pH analysis on aerobically packaged turkey hams.....	71
A.11. ANOVA table on atmosphere effect for pH analysis on turkey hams.....	72
A.12. Mean TBA numbers ^A of vacuum and aerobically packaged turkey hams held at 4°C for 0, 6, 12, and 15 days (Replication 1).....	73
A.13. Mean TBA numbers ^A of vacuum and aerobically packaged turkey hams held at 4°C for 0, 6, 12, and 15 days (Replication 2).....	74
A.14. Slopes of survival curves of <u>S. blockley</u> , <u>S. infantis</u> , and <u>S. typhimurium</u> in vacuum packaged turkey hams held at 4°C for 15 days....	75
A.15. Slopes of survival curves of <u>S. blockley</u> , <u>S. infantis</u> , and <u>S. typhimurium</u> in aerobically packaged turkey hams held at 4°C for 15 days.....	76

LIST OF TABLES (Continued)

TABLE		PAGE
A.16.	ANOVA table on main effects for the survival of <u>Salmonella</u> on vacuum packaged turkey hams....	77
A.17.	ANOVA table on main effects for the survival of <u>Salmonella</u> on aerobically packaged turkey turkey hams.....	77
A.18.	ANOVA table on atmosphere effect for the survival of <u>Salmonella</u> in turkey hams.....	78
A.19.	Mean slopes of aerobic, lactobacilli, and psychrotrophs in vacuum packaged turkey hams held at 4°C.....	79
A.20.	Mean slopes of aerobic, lactobacilli, and psychrotrophs in aerobically packaged turkey hams held at 4°C.....	80

LIST OF FIGURES

FIGURE		PAGE
1.	Reported cases of salmonellosis in the USA, 1986...	5
2.	pH values of turkey hams held at 4°C for 15 days under vacuum and aerobic conditions. All data are the mean of all treatments since treatments were not significantly ($p > 0.05$) different.....	27
3.	The survival curves of <u>Salmonella</u> in vacuum packaged turkey hams with different salt levels held at 4°C for 15 days.....	37
4.	The survival curves of <u>Salmonella</u> in aerobically packaged turkey hams with different salt levels held at 4°C for 15 days.....	38
5.	The survival curves of <u>Salmonella</u> in turkey hams with different formulations held at 4°C for 15 days under aerobic (A, broken) and vacuum (V, solid line) conditions.....	39
6.	The survival curves of <u>Salmonella</u> in turkey hams held at 4°C for 15 days under aerobic and vacuum conditions.....	45
7.	The growth curves of aerobes in turkey hams with 1.5% to 2.5% salt held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.....	47
8.	The growth curves of psychrotrophs in turkey hams with 1.5% to 2.5% salt held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.....	48

LIST OF FIGURES (Continued)

FIGURE		PAGE
9.	The growth curves of lactobacilli in turkey hams with 1.5% to 2.5% salt held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.....	49
10.	The growth curves of aerobes in turkey hams with salt (S), erythorbate (E), and STPP held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.....	51
11.	The growth curves of psychrotrophs in turkey hams with salt (S), erythorbate (E), and STPP held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.....	52
12.	The growth curves of lactobacilli in turkey hams with salt (S), erythorbate (E), and STPP held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.....	53

CHAPTER I

INTRODUCTION

Per capita turkey consumption increased 56% during the period from 1964 to 1985. Approximately, 50% was consumed in the form of processed products such as boneless turkey rolls, turkey ham, bologna and salami (23,47). In 1986 and 1987, poultry production and new poultry products in market place has risen continuously. In 1987, the per capita poultry consumption was estimated to be greater than for beef (31). Poultry, however, is frequently associated with foodborne diseases, particularly salmonellosis. In the United States, poultry ranks fourth in foods associated with disease; outbreaks of salmonellosis are more frequent from turkey (57%) than from chicken (41%) (62), and it is estimated that Salmonella infections cost the turkey industry \$10 million in product loss and consumers \$1.2 billion in medical costs yearly (28,55). In Canada, poultry ranks first or second in foods associated with disease (62), and it is turkey that cause 75% of the poultry associated cases of salmonellosis while the prevalence of Salmonella is as high as 67±7% in poultry (55). Salmonella have also been found in 12-37% of chilled and frozen turkey carcasses in the United Kingdom (14). In

cooked cured meat products, salmonellae, including heat resistant strains, e.g., S. sentenberg 775W, would almost certainly be eliminated during heat processing. However, since the environment of cured meat products is suitable for the growth of salmonellae (Table 1), recontamination, e.g., during slicing and packaging, after heat processing makes the growth of salmonellae in such products highly possible (21,58).

Since salmonellae have been recognized as an important pathogen which results in high economic loss and medical care costs, the reduction of salmonellae in poultry has become one of the most important priorities of the poultry industry (62). Few microbiological studies have been performed with processed poultry. This study was undertaken to evaluate vacuum packaging vs. air permeable overwraps for control of salmonellae in turkey ham formulated with selected levels of salt, nitrite, erythorbate, and polyphosphate.

Table 1. Comparison of physiological characteristics of salmonellae and the relevant properties of cooked cured meat.

	Salmonellae	Cooked Cured Meat
O ₂ relationships	facultatively anaerobic	vacuum-package
pH	minimum for growth, 4.5	initial value, 5.5 to 5.8
Nitrite	mic [*] 800 to 4000 ppm at pH 6.7	less than 100 ppm
Water activity	0.94 or above	0.98

* Minimum inhibitory concentration.
From Davison and Webb (21).

CHAPTER II

LITERATURE REVIEW

Salmonella is a gram-negative, flagellated, facultatively anaerobic, nonsporeforming rod. Salmonellae are pathogenic to humans, animals, or both. Ubiquitous Salmonella serotypes, e.g. S. typhimurium, are mostly responsible for food-borne infection. It is necessary to ingest 10^6 to 10^9 bacteria to express clinical symptoms such as enteric fever, acute gastroenteritis and septicemia (37,52). It has been estimated that only 1% of the cases of salmonellosis in the U.S. were reported to the authority (28,52). In 1986, there were 49,984 reported cases of salmonellosis in the U.S. (Figure 1)(17).

Several hundred different species of microorganisms have been found on poultry. Immediately after processing, chromogenic bacteria represented 50% to 60% of the total microflora on the poultry carcass while non-pigmented Pseudomonas, cocci and closely related species presented 20% to 25%. Miscellaneous bacteria represented the remaining 20% to 25% of the total microflora (6). The most common spoilage bacteria of raw refrigerated poultry are Pseudomonas, Acinetobacter and Lactobacillus. Under vacuum or CO₂ atmosphere, lactic acid bacteria predominate as a

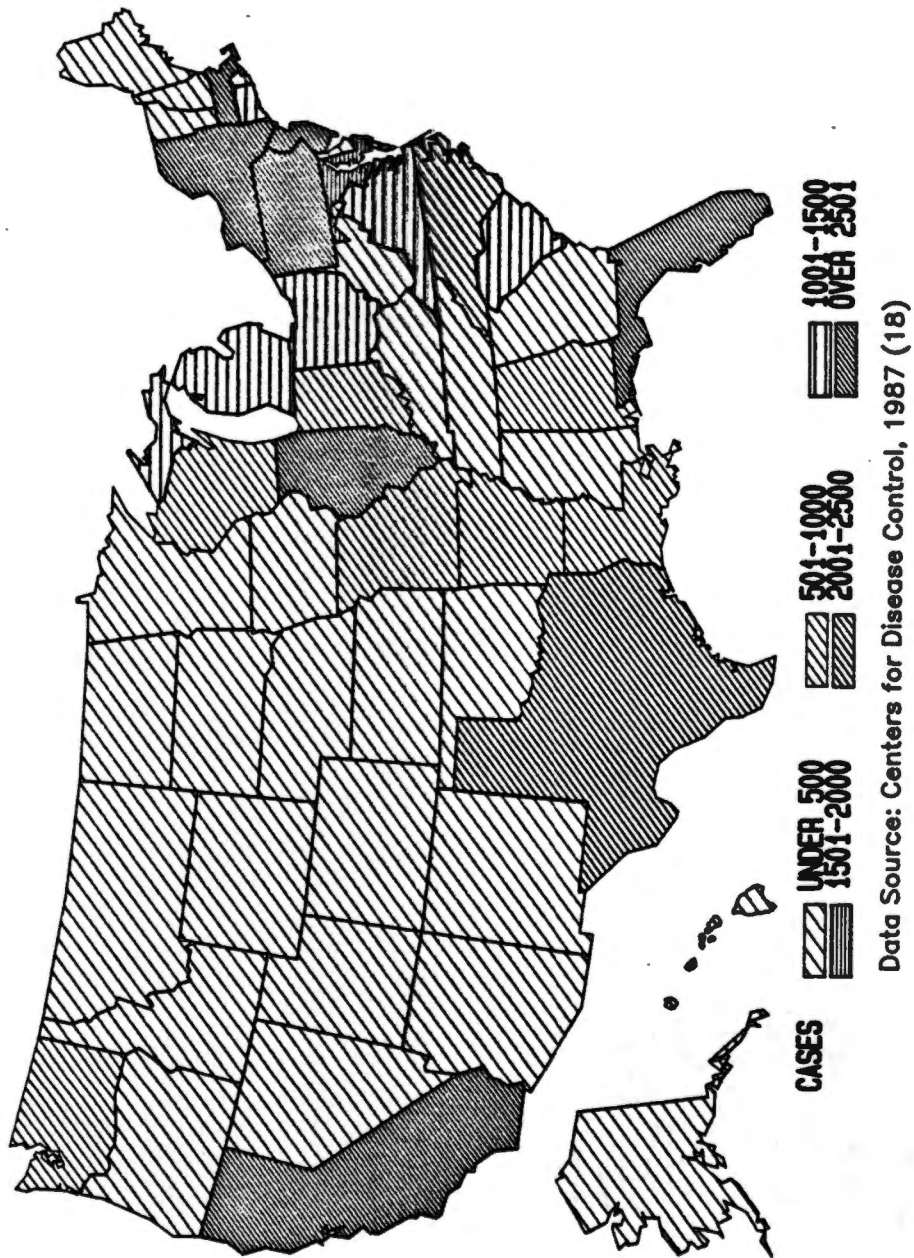


Figure 1. Reported cases of salmonellosis in the USA, 1986.

spoilage organism (6,8,29). Pseudomonas and Alcaligenes were found to be the principle microflora on spoiled cut-up poultry parts (4). Among the 224 Salmonella strains found in chicken, S. infantis was the predominant serotype; S. typhimurium was the second (62). S. typhimurium and S. san diego were found most frequently in turkey flock (53). The high incidence of Salmonella contamination on poultry products has been attributed to the dissemination of salmonellae during the scalding, picking, evisceration, and chilling operation in poultry processing plant (40).

The effectiveness of vacuum packaging in controlling aerobic bacteria, and thereby extending shelflife of meat products has been well documented (5,18,19,21,26,35). Since aerobes produce active proteolytic and lipolytic enzymes which cause off-flavor, slime and discoloration on meat products, aerobes are primarily responsible for quality losses when meat products are held aerobically (19). The use of vacuum packaging of poultry products not only extended shelflife but also prevented the growth of associated pathogenic bacteria (35,48,65). Pseudomonas spp., the predominant organism on the surface of spoiled poultry flesh during storage in air, was reported to be inhibited by storage in vacuum atmosphere (34). Wanger et al. (63) reported that the growth of mesophilic, psychrotrophic and lipolytic organisms on bacon was

inhibited with the combination of high barrier-high vacuum treatment. Krafe et al. (35) showed that vacuum packaged broilers had a longer shelflife at 5°C if a high barrier film was applied. Patterson et al. (49) also showed that vacuum packaging extended the shelflife of both breast and thigh portions of raw chicken up to 42 days at 1°C. When beef was vacuum packaged, the shelflife was greatly increased due to the replacement of aerobic bacteria by mainly lactic acid bacteria (19). In vacuum packaged cooked cured meat products, lactic acid bacteria became the predominant organism and suppressed the growth of other microbes (29). In contrast to the findings of the above studies, Davison and Webb (21) reported that, in vacuum packaged mock chicken, an inoculum of 1,000/g salmonellae increased more than ten thousandfold to about 10^7 /g after being held at 24°C for 3 days, and at 7°C storage, with an inoculum of 100 or 1000/g, the salmonellae persisted for several weeks. In the absence of sorbate, vacuum atmosphere stimulated the growth of S. enteritidis on trypticase soy agar (24). S. typhimurium survived with slight decreases in viable counts in vacuum packaged ham and chopped ham held for 30 days at 4°C and 10°C while Bacillus cereus and Clostridium perfringens in both products decreased greatly (58). Gray et al. (30) also reported that a vacuum atmosphere had no effect in

inhibiting the growth of Salmonella on fresh chicken thighs.

Salt (NaCl) has been used in meat preservation since ancient times. Salt acts by dehydration and alteration of osmotic pressure so that it inhibits bacterial growth and subsequent spoilage (50). In recent years, due to health concerns relating sodium with hypertension and subsequent cardiovascular diseases, the reduction of salt in meat products has been strongly suggested (41). It has been reported that 2.0% to 2.5% NaCl in a product had little influence on product shelflife and safety from pathogens (50). In anerobically stored, sliced cured pork shoulder, the growth of salmonellae were inhibited at a brine concentration of 5.7% but not at 2.7% at 22°C (1). Likewise, Nielsen and Zeuthen (46) reported that, in vacuum-packaged bologna-type sausage, 6% brine concentration was effective in preventing the development of S. enteritidis, S. typhimurium, Bacillus cereus and Yersinia enterocolitica. Increasing NaCl content from 1.0% to 3.0% in turkey frankfurters delayed C. botulinum toxin production by 3 days on average (12). It has been reported that low oxygen intensity enhanced the antimicrobial ability of NaCl (46).

The function of nitrite in meat curing has long been known. It stabilizes the color, produces the typical

flavor, retards the development of rancidity, and inhibits the growth of a number of food poisoning microorganisms, especially C. botulinum, in cured meat (9,39,41,54). At pH 4.5 to 5.5, nitrite has been found to have significant bactericidal properties (33). Nitrite concentrations of 400 ppm and 2500 ppm were effective in preventing aerobic bacterial growth in chicken white meat while 2500 ppm was required to prevent growth in dark meat at 4-5°C for 12 days. In chicken white meat patties, 100 to 150 ppm nitrite has been demonstrated to delay the bacterial growth for 4-10 days while 400 ppm was needed in dark meat patties to have the same effect (15). Hasiak et al. (32) reported that turkey hams containing nitrite at levels of 78, 104, and 156 ppm had a shelflife of 2 to 4 weeks longer than the products containing nitrite at levels of 0 and 52 ppm. The legal amount of nitrite in finished product is not more than 200 ppm. Farrel and Upton (25) reported that Salmonella has exhibited resistance to 200 ppm nitrite in cured meats. In recent years, because of the concern about the formation of N-nitrosamine, a carcinogen, from nitrite, a reduction of nitrite to 120 ppm, used with ascorbate or erythorbate, has been suggested (50,63).

Polyphosphates are added to the cure to increase the water-binding capacity, help emulsification, retard oxidation, and stabilize meat color by controlling pH,

increasing ionic strength and sequestering metal ions (12,44,50). Polyphosphate has been shown not only to inhibit the growth of various bacteria but also enhance the ability of sodium nitrite for inhibiting the growth of C. botulinum and its toxin production in meat products (43,45,64). Firstenberg-Eden et al. (27) report that polyphosphates inhibited colony formation of unstressed Moraxella-Acinetobacter cells on plate count agar, and when the concentration of polyphosphates was above 0.1%, the percentage of survivors was decreased progressively. The combination of polyphosphates and NaCl in deboned, ground turkey meat not only enhances the quality characteristics of restructured, cooked, dark turkey meat but also reduces thiobarbituric acid (TBA) number (36). The antimicrobial effect of polyphosphates might be due to the interference of phosphate with divalent cation metabolism via chelation (27). The legal limit for added polyphosphate is 0.5% in finished product (50).

The salts of erythorbic acid are commonly used to hasten development and stabilize the color of cured meat. Erythorbates are also used to lower the nitrite added, reduce residual nitrite level and prevent rancidity development in cured meat (50). Wesley et al. (65) reported that 550 ppm sodium erythorbate stabilized the color of turkey frankfurters over a 70-day storage period.

Hasiak et al. (32) reported that [1] 550 ppm sodium erythorbate reduced the residual nitrite levels by 15.6% in the turkey hams, especially at the level of 156 ppm sodium nitrite; [2] 550 ppm sodium erythorbate significantly increased the content of cured meat pigment, nitrosylhemochrome, in turkey hams; [3] the interaction between erythorbate and nitrite significantly decreased the TBA numbers.

Poultry meat is composed of relatively high levels of unsaturated fatty acids and low levels of natural tocopherols, making it relatively unstable (38). Turkey lipid was reported to contain more polyunsaturated fatty acids than other common animal fats (22), and, according to the report of Tarladgis (60), iron in metmyoglobin or hemoglobin was highly effective in initiating the chain-reaction mechanism in the lipid autoxidation process. Therefore, processed turkey products which contain dark meat, e.g., thigh meat, are susceptible to lipid oxidation.

CHAPTER III

MATERIALS AND METHODS

1. Ham Manufacture and Sample Preparation

Raw turkey thigh meat was purchased through Harrison's Chicken City Co. (Knoxville, TN). Turkey hams were formulated to contain 156 ppm sodium nitrite, various levels of sodium chloride, sodium tripolyphosphate (STPP), and sodium erythorbate as shown in Table 2. In the second replication, only hams with 1.5, 2.0, and 2.5% salt were formulated. The turkey ham processing procedure described by Baker and Darfler (7) and Pearson and Tauber (50) was followed to manufacture the turkey hams. Raw turkey thigh meat was ground through a one inch plate. In order to obtain 3.6 Kg sample for each treatment, 3.3 Kg thigh meat, 0.36 Kg turkey skin and 0.54 Kg ice were used in each formulation. Turkey skin was chopped to a smooth consistency in a Fatosa silent cutter (Sabadell, Spain) with ice and half the amount of salt required for each treatment. Ground turkey thigh meat, turkey skin emulsion, the remaining salt, 11.4 grams of turkey seasoning and STPP, if necessary, were then mixed together in a Hobart A-200 mixer (Hobart, Troy, Ohio) at medium speed for about 7

Table 2. Formulation of turkey hams.

Treatment No.	NaCl %	Erythorbate ^a ppm	STPP ^b ppt
1	0.5	0	0
2	1.0	0	0
3	1.5	0	0
4	2.0	0	0
5	2.5	0	0
6	3.0	0	0
7	0.5	550	0
8	1.0	550	0
9	1.5	550	0
10	2.0	550	0
11	2.5	550	0
12	3.0	550	0
13	0.5	550	5.0
14	1.0	550	5.0
15	1.5	550	5.0
16	2.0	550	5.0
17	2.5	550	5.0
18	3.0	550	5.0

^a ppm = parts per million.

^b ppt = parts per thousand.

minutes. The mixtures were stuffed into fibrous casings by a piston-type stuffer. A soft cotton thread was used for closing the casings. Cooking was done in the smoke house using the following schedule: 37.5°C for 45 min, 54°C for 90 min, 72°C for 90 min, followed by 80°C until an internal temperature of 68°C was achieved. After cooking, hams were immersed into slush ice and refrigerated overnight. The casings were removed and the hams were sliced into approximately 10 g slices and then stored at -20°C until needed.

Samples were thawed at 4°C for 48 h before use. Ten grams of samples were placed aseptically into Stomacher 400 bags (Sewardmedical, London, UK) and Cryovac bags for vacuum packaging. Samples were placed in 13x13x2.54 cm polystyrene foam trays (Mobile Chemical Co., Covington, GA) for aerobic storage; a sterile filter paper (Whatman No. 2) was placed in each polystyrene foam tray to absorb drip.

2. Sample Inoculation and Packaging

Three strains of Salmonella , S. blockley 762-55, S. infantis, and S. typhimurium 4066, were provided by Dr. B. Swaminathan (CDC, Atlanta, GA). In the second replication, only S. typhimurium 4066 and S. blockley 762-55 were studied. One-tenth milliliter of a 24 h

culture in trypticase soy broth was inoculated separately into ham slices with the inoculated side folded inside to avoid moisture evaporation (51). Uninoculated samples for microbiological and chemical analyses were also prepared. After inoculation, samples for vacuum storage treatments were vacuum packaged to 69 cm Hg vacuum in two 20x40 cm CryoVac B640BG polyethylene bags (CryoVac, W.R. Grace & Co., Simpsonville, SC). Vacuum packaging was conducted by using a Multivac 8210-2 vacuum packaging machine (CryoVac, W.R. Grace & Co., Woburn, MA). Samples for aerobic storage were overwrapped with Reynold 910 PCV film (Oxygen transmission rate: 150 cc/100 in²-24hr-ATP-per mil) (Reynolds Metals Co., Richmond, VA). Aerobic and vacuum packages were stored at 4°C for 0, 3, 6, 9, 12, and 15 days. Two replications were performed of all experiments.

3. Microbiological Analyses

A. Salmonella enumeration

Salmonella enumeration (4) was performed at each sampling period. Ten grams of sample was placed into a Stomacher 400 bag and homogenized in a Stomacher Laboratory Blender 400 (Tekmar, Cincinnati, OH) with 90 ml of sterile 0.1% peptone water for 2 min. After serial decimal

dilution was performed, 0.1 ml of inoculum from each dilution was spread on pre-poured Bismuth Sulfite Agar (BSA) (BBL, Cockeysville, MD) plates. Plates were incubated at 37°C for 48 h. Black colonies with metallic sheen were counted.

Enrichment procedure (4) was performed on control, uninoculated, samples for Salmonella enumeration. Ten grams of sample was placed in a dilution bottle containing 40 ml of lactose broth (BBL, Cockeysville, MD), pre-enrichment broth, and shaken to release bacteria from the sample into the lactose broth. After the bottle was incubated at 37°C for 24 h, 5 ml of inoculum was transferred into a test tube containing 5 ml of double-strength selenite cystine (BBL, Cockeysville, MD) selective enrichment broth. After 24 h incubation at 37°C, 0.1 or 0.5 ml of inoculum was spread on a BSA plate and incubated at 37°C for 48 h. Suspect colonies were confirmed by inoculating them into triple sugar iron agar (TSI) slants, and incubating at 37°C for 48 hr. Hydrogen sulfide, acid, and gas production on TSI indicated the presumptive existence of Salmonella in control sample.

B. Total microbial counts

Aerobic plate count (APC), lactic acid bacteria plate count (LPC), and psychrotrophic plate count (PPC) (4) were performed at each sampling period. Ten grams of uninoculated sample was placed in a sterile Stomacher 400 bag and stomached with 90 ml of sterile 0.1% peptone water in a Stomacher Lab Blender for 2 min. Serial dilutions were then performed. Pour-plates were prepared using standard methods agar (SMA) (BBL, Cockeysville, MD) for APC (aerobic mesophiles) and ATP lactics medium (BBL, Cockeysville, MD). Spread-plates were prepared using SMA for PPC. Times and temperatures of incubation were 48 h at 32°C for APC, 72 h at 35°C for LAC, and 10 days at 7°C for PPC.

4. Compositional Analyses

Moisture content of samples were determined by vacuum oven drying (AOAC: 24.002)(3). Approximately 2 g of sample was put into a pre-dried ashless filter paper 'bag', and the bag was placed into a vacuum oven (Precision Scientific, Chicago, IL) and heated at 95-100°C under 100 mm Hg vacuum until constant weight was obtained.

Protein content of samples was determined by the Kjeldahl nitrogen method (AOAC: 24.058)(3). In the distillation procedure, boric acid was used to absorb distilled ammonia and the final solution was titrated with 0.1 N HCl. Protein content was obtained by multiplying nitrogen content by 6.25.

Fat was determined using a Soxhlet extraction (AOAC: 24.005)(3). Sample left after moisture analysis was placed in Soxhlet fat extraction apparatus and fat was extracted with anhydrous ether (Mallinckrodt, Paris, KY) for 11 hr. After extraction, sample was dried in a vacuum oven for 6 h at 100 to 102°C.

Ash content was determined by placing 5-10 g of sample in a pre-dried crucible and heating in an oven at about 525°C until white ash was obtained (AOAC:24.009)(3).

All compositional analyses were performed in duplicate or triplicate.

5. Nitrite and TBA Analyses

Nitrite analysis was performed at the beginning and the end of storage period in duplicate using the sulfanilic acid method (AOAC: 24.044)(3). Nitrite was extracted from the sample with hot water. A portion of the extract was reacted with Greiss reagent containing sulfanilic acid and

N-1-naphthyl-ethylenediamine (Mallinckrodt, Paris, KY). Color development was measured in a Shimadzu UV-190 double-beam spectrophotometer (Shimadzu, Kyoto, Japan) at 520 nm. Nitrite concentration in ppm was determined from a standard curve containing 0-55 ppm of nitrite (Sigma, St. Louis, MO).

TBA analyses were performed in duplicate at day 0, 6, and 12 of storage using the modified 2-thiobarbituric acid method of Zipser and Watts (67). A ten gram sample was heated in a Kjeldahl flask with 4 N HCl to release malonaldehyde. Malonaldehyde was then reacted with 2-thiobarbituric acid to give a red pigment. Absorbance was measured with a Shimadzu UV-190 double-beam spectrophotometer at 538 nm. TBA number was obtained by multiply the absorbance value by the correction factor, 7.8, determined by Tarladgis et al. (61).

6. Salt Analysis

Salt analysis was performed in duplicate at the beginning and the end of the storage period. Salt content was determined using the Volhard method (AOAC: 24.010)(3). Approximately 2 g of sample was placed in a 250 ml Erlenmeyer flask. Five milliliters of 0.5 N silver nitrate (Fisher, Fair Lawn, NJ) was added to moisten the sample,

and then 15 ml of nitric acid (Mallinckrodt, Paris, KY) was added. The flask was heated on a hot plate until the sample was dissolved. Concentrated potassium permanganate (Fisher, Fair Lawn, NJ) was added in small portions when solution started boiling, and the solution was kept boiling until permanganate color disappeared and the solution became colorless or nearly so. Twenty-five milliliters of distilled water was added, and the solution boiled for another 5 min. The solution was then allowed to cool and water was added to a total volume of 150 ml. Five milliliters of ferric indicator (Mallinckrodt, Paris, KY) and 10 ml of diethyl ether (Mallinckrodt, Paris, KY) were added to the solution. The solution was titrated with 0.1 N ammonium thiocyanate (Mallinckrodt, Paris, KY) until a permanent light brown end point. Percent salt was calculated with the following formula:

$$\%NaCl = (ml \text{ AgNO}_3 \times N \text{ AgNO}_3) - (ml \text{ NH}_4\text{SCN} \times 0.1 N) / \text{Wt. sample}$$

7. pH and Titratable Acidity

Titratable acidity and pH were determined at each sample period; titratable acidity was performed in duplicate. Ten grams of sample was homogenized in a Waring commercial blender with 100 ml of distilled water for 1 min. The pH of the homogenized sample was measured using a

pH indicator strip (American Scientific Products, McGaw Park, IL). The slurry of sample then was filtered and filtrate was titrated with 0.1 N NaOH to the phenolphthalein end point (AOAC: 22.058)(3). The amount of acid presented as lactic acid was calculated with the following formula:

$\% \text{Acidity} = (\text{ml NaOH}) \times (\text{N NaOH}) \times 0.009 / \text{Wt. of sample in gram}$

8. Statistical Analyses

The data were subjected to various statistical analyses using the Statistical Analysis System (SAS) (61) and Statgraphics software (54). Microbiological data were transformed into logarithms before analyses. Linear regression was used to compare the microbial growth, titratable acidity (TA), and pH values obtained with different formulations and storage methods. The General Linear Models (GLM) procedure was used to perform the analysis of variance (ANOVA). GLM, with least square means and Duncan's multiple range test (57) options, was performed to separate treatment means. All statistical analyses were based on a 5% significance level.

CHAPTER IV

RESULTS AND DISCUSSION

1. Proximate Analyses

Results of proximate analyses are presented in Table 3. Hams containing 3.0% NaCl+E (550 ppm erythorbate) had the lowest ($p < 0.05$) moisture content (48.09%) and the highest ($p < 0.05$) fat content (22.84%). Although individual treatments had significantly ($p < 0.05$) higher or lower moisture contents (Table 3), moisture content of turkey hams was not significantly different ($p < 0.05$) overall among different salt levels or with the addition of erythorbate and STPP (Table 4) when main effects were evaluated. At least 2.0% salt has been reported to be required in restructured meat to give satisfactory water holding capacity (66). However, in our study, turkey hams formulated with salt levels less than 2.0% showed good moisture retention (Table 3). This may be due to the use of turkey skin in the formulation. Skin contains a high level of collagen which has been reported to improve tenderness of restructured meat products, partially due to increasing the water holding capacity (20,56). The addition of phosphates to restructured meat formulation

Table 3. Proximate composition of turkey hams prepared with six salt levels, erythorbate, nitrite, and STPP, alone and in combination.

Treatment ^A	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
0.5% NaCl	64.37cd ^B	15.35ab	20.60ab	1.37a
1.0% NaCl	64.40cd	12.23a	20.60ab	1.72abc
1.5% NaCl	68.31d	12.40a	19.92ab	1.97abcd
2.0% NaCl	62.78bcd	15.82ab	18.34ab	2.44abcd
2.5% NaCl	59.94bcd	16.08ab	19.48ab	2.61abcd
3.0% NaCl	65.24d	14.51ab	19.80ab	3.19def
0.5% NaCl+E	64.27cd	14.34ab	21.25ab	1.54ab
1.0% NaCl+E	61.89bcd	15.85ab	18.34a	1.60ab
1.5% NaCl+E	63.35d	11.76a	19.72ab	1.60ab
2.0% NaCl+E	66.96d	13.36a	18.92ab	2.41abcd
2.5% NaCl+E	67.63d	11.41a	18.60a	2.71bcde
3.0% NaCl+E	48.09a	22.84b	20.58ab	3.95ef
0.5% NaCl+E+P	62.87bcd	15.92ab	22.28b	1.51ab
1.0% NaCl+E+P	66.28d	14.06ab	19.53ab	2.11abcd
1.5% NaCl+E+P	63.35cd	13.50a	18.87ab	2.21abcd
2.0% NaCl+E+P	54.30abc	18.49ab	21.26ab	2.66bcd
2.5% NaCl+E+P	64.42d	13.94a	18.40a	2.91cde
3.0% NaCl+E+p	52.87ab	18.33ab	18.21a	4.33f

^AE=550 ppm erythorbate, and P=0.5% STPP (sodium tripolyphosphate).

^BMeans in columns followed by same letters are not significantly different ($P > 0.05$).

Table 4. Main effects on proximate composition in turkey hams formulated with selected levels of salt, erythorbate, and STPP.

Treatment	Means (%)			
	Protein	Fat	Moisture	Ash
NaCl levels				
1.5%	19.45 a ^A	12.55 a	63.68 a	1.93 a
2.0%	19.08 a	15.89 a	67.76 a	2.50 b
2.5%	19.51 a	13.81 a	60.69 a	2.74 b
STPP ^B				
0	19.51 a	14.77 a	63.68 a	2.34 a
0.5%	18.83 a	15.31 a	60.69 a	2.59 a
Erythorbate				
0	19.51 a	14.77 a	67.76 a	2.34 a
550 ppm	19.71 a	12.18 a	63.68 a	2.24 a

^AMeans within treatment groups followed by different letters are significantly different ($p < 0.05$).

^BAlso includes 550 ppm erythorbate.

with at least 1.5% salt has been reported to improve moisture retention (10,42,56). However, addition of STPP appeared to have no significant effect ($p > 0.05$) on moisture retention (Table 3) in our study.

Fat content of samples ranged from 11.41% to 22.84% (Table 3). In general, turkey hams having the lower moisture content were higher in fat content (Table 3). This may be due to the water loss increasing fat content on a weight basis. Although fat content of several treatments was significantly ($p < 0.05$) lower than the 22.84% found in the 3.0% NaCl+E treatment, analysis of the main effects of NaCl, erythorbate, and STPP showed no significant ($p > 0.05$) difference overall.

The protein content of turkey hams ranged from 18.21% to 22.28% (Table 3). Different formulation had no significant effect ($p > 0.05$) on the protein content of turkey hams (Table 3) .

Ash analysis of turkey hams showed that ash increased ($p < 0.05$) with the addition of salt (Tables 3 and 4). Erythorbate and STPP had no significant effect ($p > 0.05$) on the ash content of turkey hams (Table 4). An increment of 0.5% NaCl increased ash content approximately 0.30%. Addition of 0.50% STPP increased the mean ash content approximately 0.20% while erythorbate had no effect on increasing ash content.

2. pH and Titratable Acidity

Changes in pH of turkey hams during storage at 4°C for 15 days under aerobic and vacuum packaging are presented in Figure 2. The initial pH values of turkey hams ranged from 6.2 to 6.5. Only one figure is presented for all treatments stored under each atmosphere since treatments were not significantly different ($p > 0.05$) (Tables 5 and 6). STPP has been previously reported to significantly increase the pH value of restructured meat (11,42); however, the pH values of turkey hams did not change significantly ($p > 0.05$) among different formulation in our study when held at 4°C for 15 days under vacuum conditions (Table 6). Generally, pH values of turkey hams held under aerobic packaging increased slightly with storage time, however, pH of vacuum packaged turkey hams was stable (Figure 2).

Slopes of regression lines representing changes in titratable acidity (TA) of uninoculated samples during storage are shown in Table 5. Slopes for TA changes among treatments formulated with different salt levels, erythorbate, and STPP or held different atmosphere were not significantly different ($p > 0.05$) (Table 6).

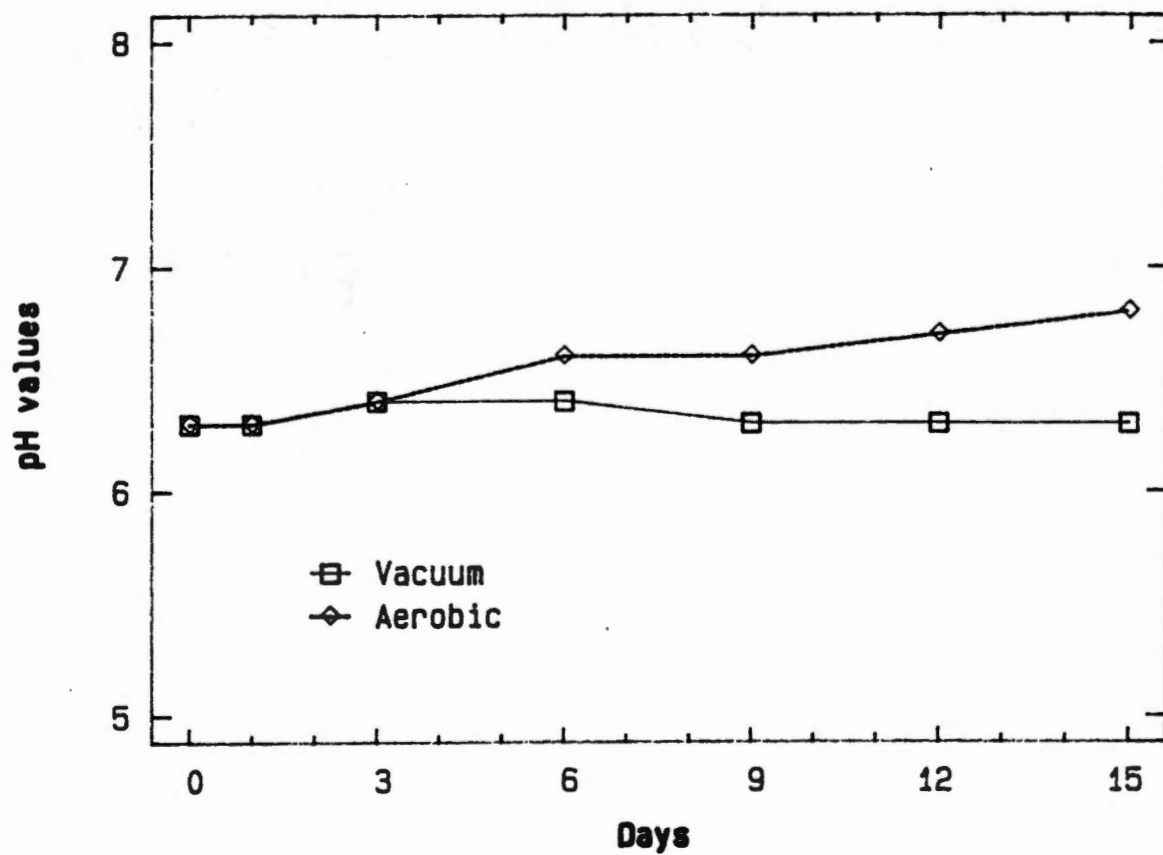


Figure 2. pH values of turkey hams held at 4°C for 15 days under vacuum and aerobic conditions. All data are the mean of all treatments since treatments were not significantly ($p > 0.05$) different.

Table 5. Slopes of pH and titratable acidity for turkey hams packaged under vacuum or aerobic conditions and held at 4°C.

Treatment ^A	Slopes of TA ($\times 10^{-2}$)		Slopes of pH ($\times 10^{-2}$)	
	Vacuum	Aerobic	Vacuum	Aerobic
0.5% NaCl	0.32 ^B	4.00	0.34	9.26
1.0% NaCl	0.79	0.14	-1.22	7.08
1.5% NaCl	0.72	0.82	-1.27	0.32
2.0% NaCl	0.25	-0.82	-1.79	-4.73
2.5% NaCl	0.25	0.81	-0.33	0.30
3.0% NaCl	0.64	0.68	-1.86	-1.10
0.5% NaCl+E	0.51	3.04	-2.93	10.95
1.0% NaCl+E	0.32	-0.51	-1.87	8.79
1.5% NaCl+E	0.83	1.37	-0.83	2.07
2.0% NaCl+E	0.44	-0.08	-1.18	0.25
2.5% NaCl+E	0.05	-0.51	-0.85	2.20
3.0% NaCl+E	0.26	0.30	1.24	2.83
0.5% NaCl+E+P	0.49	-1.41	-2.02	3.37
1.0% NaCl+E+P	0.13	-2.16	-1.18	4.37
1.5% NaCl+E+P	0.23	0.47	0.75	1.10
2.0% NaCl+E+P	0.58	0.10	-0.32	3.56
2.5% NaCl+E+P	0.52	-0.02	-0.57	1.27
3.0% NaCl+E+P	0.55	-0.37	0.45	2.56

^AE=550 ppm erythorbate and P=0.5% STPP.

^BMean pH and TA slopes are presented to show the range of values obtained. Mean were not significantly different ($p > 0.05$).

Table 6. Mean changes of pH and TA (slope) by treatment in turkey hams held under vacuum and aerobic atmospheres at 4°C for 15 days.

Treatment	TA ($\times 10^{-2}$)		pH ($\times 10^{-2}$)	
	Vacuum	Aerobic	Vacuum	Aerobic
Salt levels				
0.5%	0.44 a ^A	-0.15 a	-1.54 a	7.86 a
1.0%	0.41 a	-0.84 a	-1.42 a	6.75 a
1.5%	0.59 a	0.89 a	-0.54 a	1.16 a
2.0%	0.42 a	-0.27 a	-1.10 a	-0.31 a
2.5%	0.27 a	0.09 a	-0.58 a	1.26 a
3.0%	0.48 a	0.21 a	-0.06 a	1.43 a
Erythorbate				
0	0.50 a	0.94 a	-1.02 a	1.86 a
550 ppm	0.40 a	0.60 a	-1.07 a	4.50 a
STPP^B				
0	0.40 a	0.60 a	-1.07 a	4.50 a
0.5%	0.42 a	-0.57 a	-0.48 a	2.70 a
Atmospheres				
vacuum	0.44 a		-0.86 a	
aerobic	-0.01 a		3.86 a	

^A Means in columns within treatment groups followed by same letters are not significantly different ($p > 0.05$).

^B Also includes 550 ppm erythorbate.

3. Lipid Oxidation

TBA values, as an indicator of lipid oxidation, of turkey hams held at 4°C for 15 days under aerobic or vacuum atmospheres for replication 1 and replication 2 are presented in Appendix 12 and Appendix 13. During the 15-day storage period, TBA values of turkey hams varied over time and no significant differences among means were found ($p > 0.05$). However, TBA values generally increased over time except with three treatments under each packaging method used. This finding agrees with that reported by several researchers that malonaldehyde, the reactive substance in the TBA analysis, did not accumulate as a stable end product of fat oxidation (13,42,60). It has been suggested that the decline of TBA values during storage may be partially due to the interaction of myosine and malonaldehyde. In replication 2, turkey hams formulated with erythorbate and STPP had significantly lower ($p < 0.05$) TBA values (Table 7). The antioxidation abilities of erythorbate and STPP through ion-chelation has been widely reported (12,44,50). In replication 1, turkey hams formulated with the addition of erythorbate and/or STPP also had lower TBA values (Table 7), however, these differences were not significant ($p > 0.05$).

Table 7. Main effects on TBA values of turkey hams formulated with selected levels of salt, erythorbate, and STPP.

Treatment	Means	
	Replication 1	Replication 2
NaCl levels		
1.5%	0.689 a ^A	0.351 a
2.0%	0.809 a	0.341 a
2.5%	0.882 a	0.374 a
Erythorbate		
0	1.031 a	0.598 a
550 ppm	0.436 a	0.290 a
STPP ^B		
0	1.031 a	0.598 a
0.5%	0.905 a	0.177 b
Atmosphere		
vacuum	0.889 a	0.324 a
aerobic	0.692 a	0.386 a
Storage days		
0	0.548 a	0.337 a
6	0.791 a	0.399 a
12	0.893 a	0.342 a
15	0.902 a	0.342 a

^AMeans in columns within treatment group followed by same letters are not significantly different ($p > 0.05$).

^BAlso includes 550 ppm erythorbate.

TBA numbers during storage under different atmospheres were not significantly ($p > 0.05$) different (Table 7). Sixty-two percent of the lipid in turkey meat is unsaturated fatty acids which are very susceptible to oxidation (2,13). Treatments in Table 3 having some of the the highest fat contents also had some of the highest TBA values after storage. Turkey hams in our study were frozen before using. Buttkus (16) reported that the interaction of myosin and malonaldehyde was accelerated due to the concentration during freezing. Off-odors and rancid flavors in meat were first detected when TBA values were in the range of 0.5 to 2.0 mg malonaldehyde/Kg sample (61). Most samples in our study formulated without erythorbate or STPP exceeded a TBA value of 0.5 mg malonaldehyde/Kg sample at some time in their storage under either vacuum or aerobic storage.

4. Nitrite

The results of nitrite analysis are presented in Table 8. Nitrite was analyzed at the time of sample inoculation and after 15-days storage at 4°C. When main effects were evaluated (Table 9), STPP and the combinations of erythorbate and STPP were found to significantly ($p < 0.05$) decrease residual nitrite. These results are in agreement

Table 8. Initial and final concentration^A (ppm) of nitrite in vacuum and aerobically packaged turkey hams.

Treatment ^B	Residual Nitrite Levels (ppm)		
	0 days	<u>Vacuum</u> 15 days	<u>Aerobic</u> 15 days
1.5% NaCl	96.87	67.68	60.42
2.0% NaCl	85.88	67.68	74.98
2.5% NaCl	82.27	48.51	60.40
Means	88.34	63.28 ^C	
1.5% NaCl+E	104.13	67.69	67.70
2.0% NaCl+E	64.09	45.83	53.12
2.5% NaCl+E	49.44	60.41	67.70
Means	72.52	60.48	
1.5% NaCl+E+P	45.82	23.96	31.25
2.0% NaCl+E+P	49.44	45.84	31.25
2.5% NaCl+E+P	35.08	38.54	45.84
Mean	43.45	36.11	

^A Analysis was performed at day 0 and 15.

^B E=550 ppm erythorbate and P=0.5% STPP.

^C Percent reduction was calculated as follows:
 $100\% - (\text{final nitrite level} / \text{initial nitrite level} \times 100\%)$.

Table 9. Mean residual nitrite by main treatment effect in turkey hams held at 4°C for 15 days.

Treatment	Mean Residual Nitrite (ppm)
NaCl levels	
1.5%	62.84 a ^A
2.0%	57.57 a
2.5%	54.24 a
STPP ^B	
0	71.63 a
0.5%	38.56 b
Erythorbate	
0 ppm	71.63 a
550 ppm	64.46 a
Atmosphere	
aerobic	54.74 a
vacuum	51.79 a
Storage	
0	68.11 a
15 days	53.27 b

^A Means within treatment followed by different letters are significantly different ($p < 0.05$).

^B Also includes 550 ppm erythorbate.

with research literature which shows that erythorbate enhances the formation of nitrous acid, the active form of nitrite, and, thereby, decreases residual nitrite (16,33). Wesley et al. (65) reported that erythorbate reduced the residual nitrite by 15.6% in franks made from deboned turkey. The average nitrite level in turkey hams at the time of sampling (Table 8) was found to be higher (88.34 ppm) in treatments without erythorbate and STPP. The average nitrite levels were 72.52 ppm for turkey hams formulated with erythorbate, and 43.45 ppm for hams formulated with erythorbate and STPP. Average residual nitrite reduction over all treatments after storage at 4 C for 15 days was 16.60% due to the addition of erythorbate and was 16.89% due to the addition of erythorbate and STPP (Table 8). The decline in nitrite level in red meat systems during storage has been reported, and showed that nitrite decline was typically curvilinear (65). The residual nitrite levels in turkey hams were not significantly different ($p > 0.05$) between storage methods and among salt levels. Residual nitrite levels during the 15-day storage period decreased significantly ($p < 0.05$) (Table 9).

5. Salmonella

Salmonella was not isolated from any uninoculated turkey ham in the study. Survival curves of Salmonella spp. in vacuum and aerobically packaged turkey hams formulated with six levels of NaCl are shown in Figures 3 and 4. Salmonella strains were not significantly different ($p > 0.05$); therefore, all data is the mean of the three species studied. Salmonella were inoculated into turkey hams at a level of 10^5 to 10^6 CFU/g (Figures 3 and 4). Salmonella declined only slightly in turkey hams held under aerobic and vacuum packaging at 4°C for 15 days (Figures 3 and 4). The maximum decline in Salmonella was log 2.0 CFU/g and log 1.5 CFU/g in turkey hams containing 3.0% salt under aerobic and vacuum packaging respectively. Under aerobic packaging, turkey hams containing 0.5% and 1.0% NaCl had greater declines in Salmonella numbers than hams containing 1.5%, 2.0% or 2.5% NaCl.

The overall effects of NaCl, erythorbate and STPP on the survival of Salmonella in turkey hams under aerobic and vacuum packaging are shown in Figure 5. Survival of Salmonella decreased from approximately log 6.0 CFU/g to less than log 5.0 CFU/g with the addition of erythorbate and STPP under aerobic packaging (Figure 5). However, erythorbate and STPP showed no inhibitory effect on

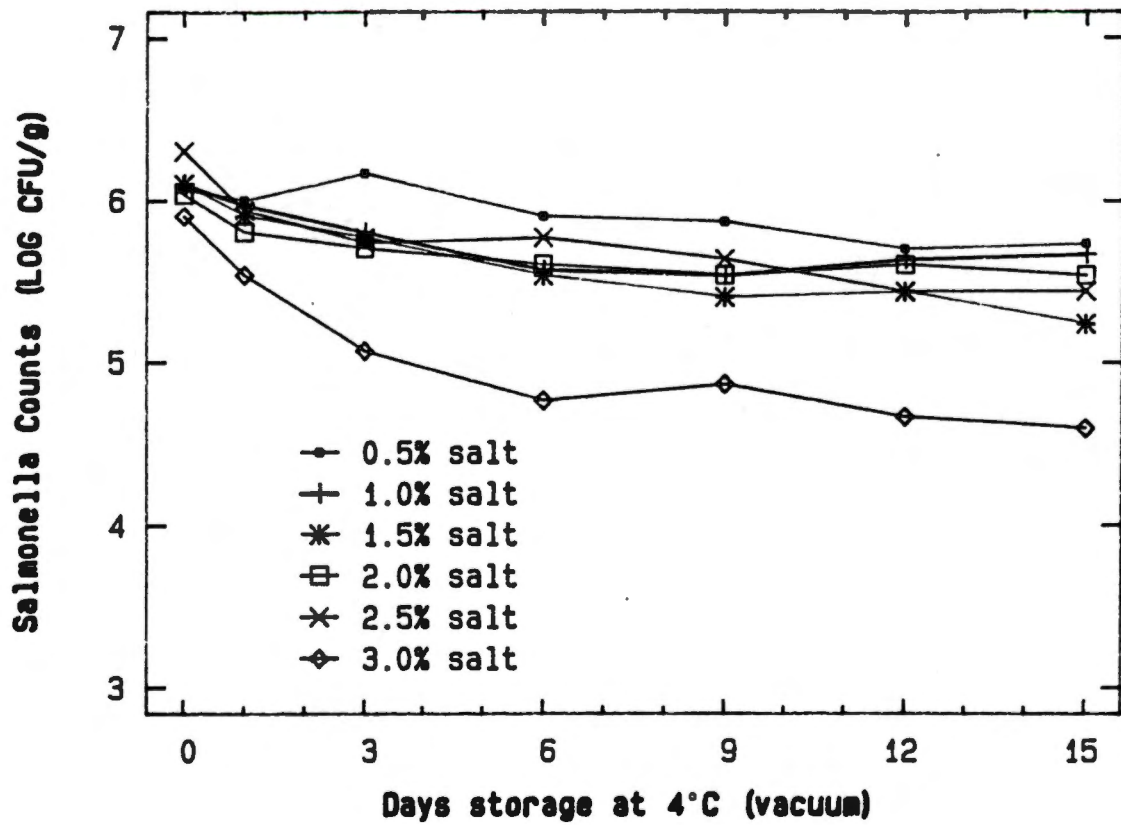


Figure 3. The survival curves of Salmonella in vacuum packaged turkey hams with different salt levels held at 4°C for 15 days.

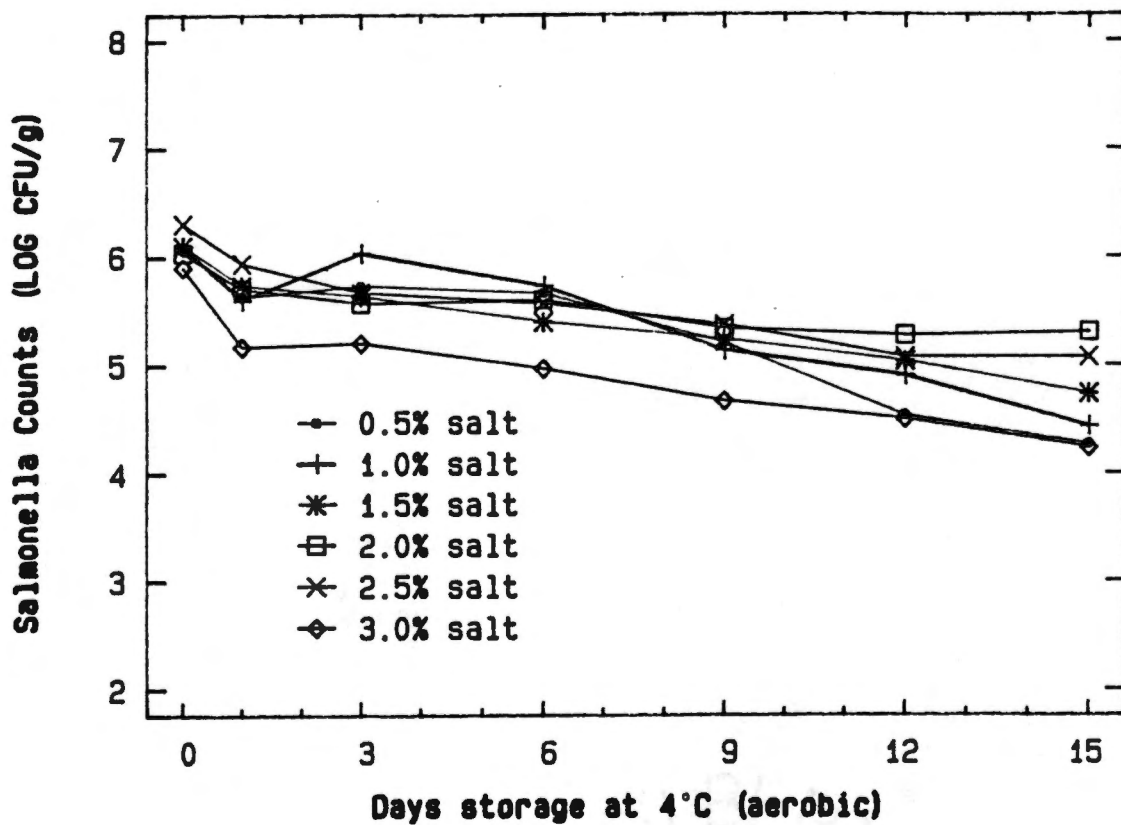


Figure 4. The survival curves of Salmonella in aerobically packaged turkey hams with different salt levels held at 4°C for 15 days.

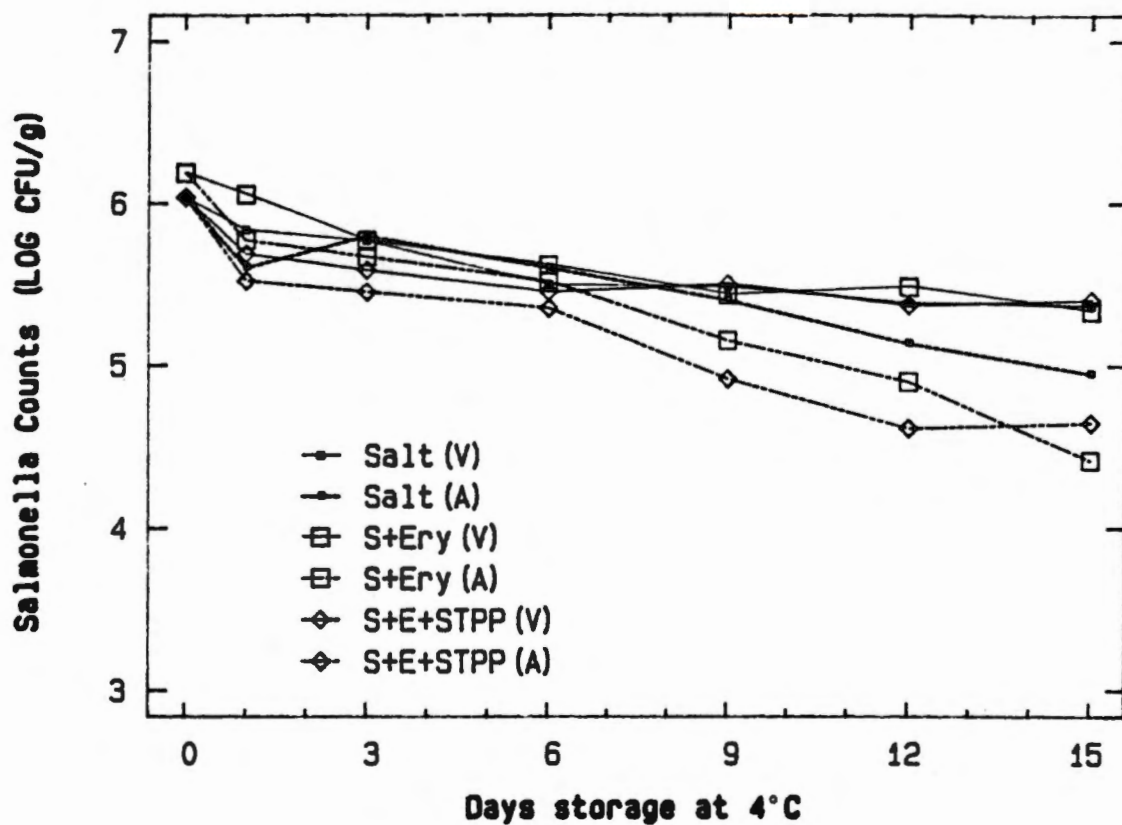


Figure 5. The survival curves of Salmonella in turkey hams with different formulations held at 4°C for 15 days under aerobic (A, broken line) and vacuum (V, solid line) conditions.

Salmonella under vacuum packaging (Figure 5). Regression equations were calculated for survival of Salmonella under each treatment over the 15-day storage period at 4°C. Since the y-intercept of each treatment was similar, slopes of each treatment were used to compare the main effects of NaCl, erythorbate and STPP on survival of Salmonella over time. Mean separations after analysis of variance of slopes of survival curves of Salmonella for NaCl, erythorbate and STPP treatments are presented in Table 10. All slopes were negative, indicating that Salmonella levels decreased in all treatments. When main effects were evaluated, survival of Salmonella in turkey hams was significantly decreased ($p < 0.05$) as salt levels increased under vacuum packaging. Significant decreases ($p < 0.05$) in survival of Salmonella under aerobic packaging occurred at the 2.0% to 2.5% NaCl level as compared to 1.0% NaCl. Survival of Salmonella was not significantly ($p > 0.05$) different by the combination of erythorbate and STPP under vacuum and aerobic conditions (Table 10)(Figure 5).

Fairly large numerical differences were observed in slopes of Salmonella survival curves under aerobic packaging in Table 10 without statistically significant differences at the 0.05 level. Although slopes provide a rapid and useful technique for comparing survival curves, a

Table 10. Main effects of selected levels of salt, erythorbate, STPP on mean slopes of survival curves of Salmonella in vacuum and aerobically packaged turkey hams stored at 4°C for 15 days.

Treatment	Mean Slopes($\times 10^{-2}$)	
	Vacuum	Aerobic
Salt levels		
0.5%	-2.289 a ^A	-8.337 ab
1.0%	-3.750 ab	-8.201 b
1.5%	-5.511 bc	-6.347 ab
2.0%	-3.513 ab	-5.544 a
2.5%	-4.861 abc	-6.694 a
3.0%	-6.394 c	-8.957 ab
Erythorbate		
0	-4.507 a	-5.566 a
550 ppm	-4.591 a	-8.816 a
STPP^B		
0	-4.591 a	-8.816 a
0.5%	-4.061 a	-9.722 a
Atmosphere		
Vacuum	-4.386 a	
Aerobic	-8.034 b	

^A Means within treatment groups followed by same letters are not significantly different ($p > 0.05$)

^B Also includes 550 ppm erythorbate.

difficulty was encountered in their use. Lag phases of survival curves and growth curves vary with each treatment, and strongly influence the calculated slope. Possible statistical method for handling this problem need further study.

Mean slopes of survival curves of Salmonella spp. for individual treatments under aerobic packaging are presented in Table 11. Treatments containing the lowest salt level of 0.5% in combination with erythorbate and/or STPP significantly ($p < 0.05$) decreased survival of Salmonella in turkey ham (Table 11). Mean slopes for survival curves of Salmonella in turkey ham under vacuum packaging are shown in Table 12. Mean survival slopes were significantly ($p < 0.05$) more negative at salt levels of 2.5% or greater. Survival slopes were not significantly ($p > 0.05$) different between 3.0% salt and 2.5% salt. Slopes for survival of Salmonella in turkey hams formulated with and without erythorbate and/or STPP did not differ significantly ($p > 0.05$) under vacuum packaging. Survival of Salmonella was significantly ($p < 0.05$) greater in vacuum storage than in aerobic storage (Table 10)(Figure 6).

Means slope data in Table 11 (aerobic packaging) and Table 12 (vacuum packaging) demonstrate that the effect of NaCl, erythorbate and STPP on survival of Salmonella is

Table 11. Mean slopes of three strains of Salmonella in aerobically packaged turkey hams held at 4°C.

Treatment ^A	Mean Slopes (x10 ⁻²)	Homogeneous Groups ^B
0.5% NaCl	-1.883	a
1.5% NaCl+E	-4.810	a b
2.0% NaCl	-4.918	a b
2.5% NaCl	-5.138	a b
2.0% NaCl+E	-5.314	a b
2.5% NaCl+E	-5.422	a b
1.5% NaCl	-5.940	a b c
2.0% NaCl+E+P	-6.726	a b c
1.0% NaCl+E	-7.733	a b c d
3.0% NaCl	-8.340	a b c d
2.5% NaCl+E+P	-8.794	a b c d
3.0% NaCl+E+P	-9.080	a b c d
3.0% NaCl+E	-9.317	a b c d
1.5% NaCl+E+P	-9.438	a b c d
0.5% NaCl+E+P	-11.176	b c d
1.0% NaCl	-13.903	c d e
1.0% NaCl+E+P	-15.267	d e
0.5% NaCl+E	-19.233	e

^AE=550 ppm erythorbate and P=0.5% STPP.

^BMeans in columns followed by same letters are not significantly different ($p > 0.05$).

Table 12. Mean slopes of survival curves from three strains of Salmonella in vacuum packaged turkey hams held at 4°C.

Treatment ^A	Mean Slopes (x10 ⁻²)	Homogeneous Groups ^B
0.5% NaCl+E+P	-0.070	a
0.5% NaCl	-0.867	a b
2.0% NaCl	-1.936	a b c
1.0% NaCl+E+P	-2.467	a b c
1.5% NaCl+E	-3.804	a b c d
1.5% NaCl+E+P	-3.804	a b c d
1.0% NaCl+E	-3.860	a b c d
2.0% NaCl+E+P	-3.958	a b c d
2.0% NaCl+E	-3.982	a b c d
2.5% NaCl+E	-4.604	b c d e
1.0% NaCl	-4.743	b c d e
2.5% NaCl	-4.804	b c d e
3.0% NaCl	-5.260	c d e
2.5% NaCl+E+P	-5.350	c d e
3.0% NaCl	-5.417	c d e
0.5% NaCl+E	-5.930	c d e
1.5% NaCl	-7.002	d e
3.0% NaCl+E+P	-8.497	e

^AE=550 ppm erythorbate and P=0.5% STPP.

^BMeans in columns followed by same letters are not significantly different ($p > 0.05$).

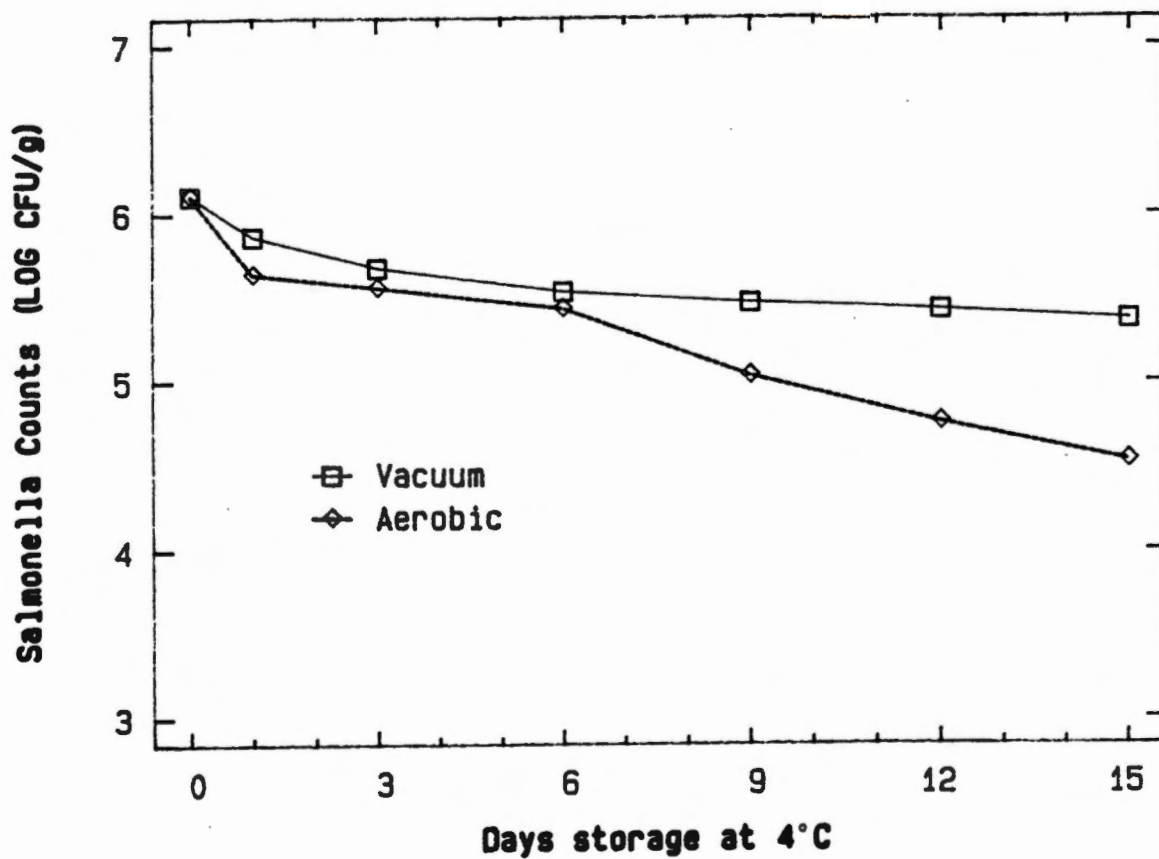


Figure 6. The survival curves of *Salmonella* in turkey hams held at 4°C for 15 days under aerobic and vacuum conditions.

very dependent upon the type of packaging used. Higher salt levels were significantly ($p < 0.05$) more inhibitory to Salmonella under vacuum packaging, but had no significant ($p > 0.05$) effect under aerobic packaging. Lower salt levels, particularly in combination with erythorbate or STPP, were significantly ($p < 0.05$) more inhibitory than other treatments under aerobic packaging. Based on these findings, the packaging method, as well as, formulation must be considered to optimize safety of turkey hams.

6. Aerobes, Lactobacilli, and Psychrotrophs

The initial bacterial load of turkey ham was between 10^1 to 10^3 CFU per gram sample (Figures 7,8, and 9).

Aerobic plate count (APC) increased rapidly from log 2.6 CFU/g to log 5.0 CFU/g under aerobic packaging in formulations containing 2.0% NaCl (Figure 7). Formulations containing 1.5% NaCl increased from log 2.2 CFU/g to log 4.6 CFU/g after 12 days at 4°C. APC under vacuum packaging either remained fairly stable or increased only slightly in turkey ham held at 4°C for 12 days. All treatments except for 1.5% NaCl (aerobic) had sharp increases in APC/g between 12 and 15 days of storage.

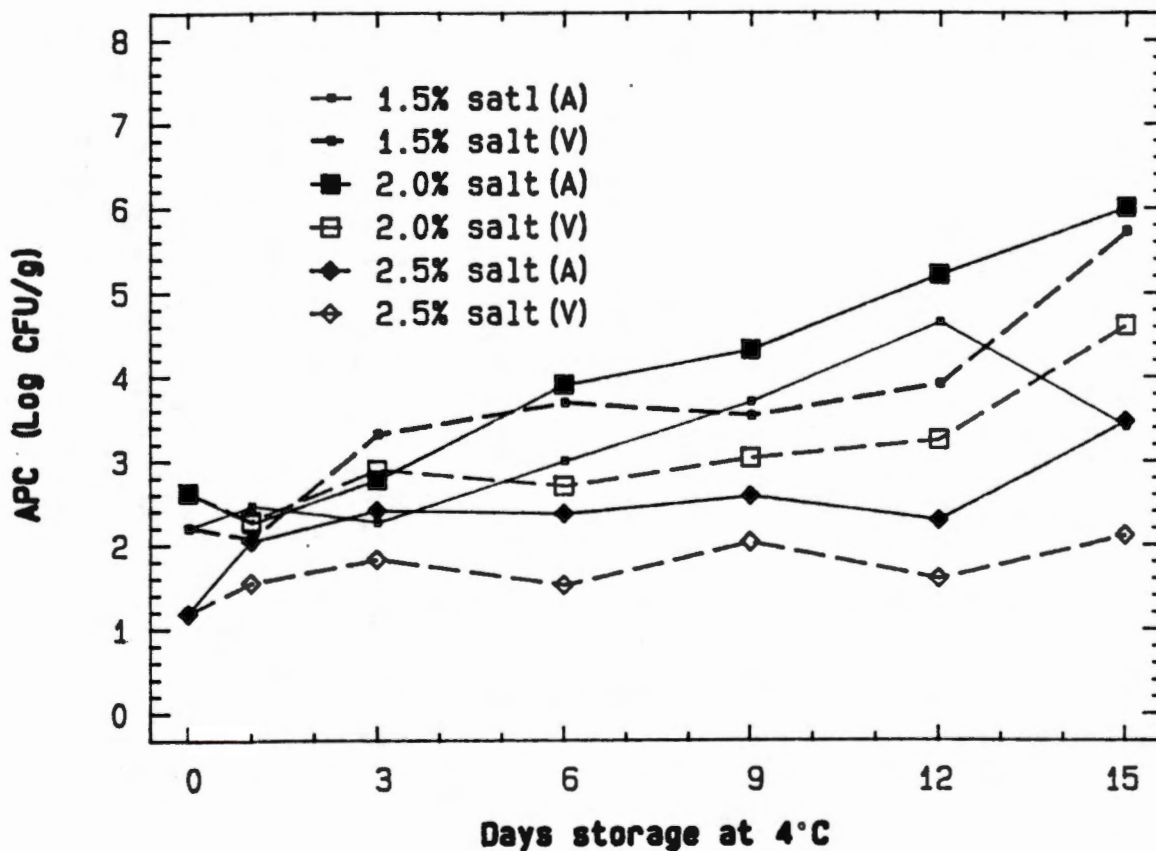


Figure 7. The growth curves of aerobes in turkey hams with 1.5% to 2.5 % salt held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.

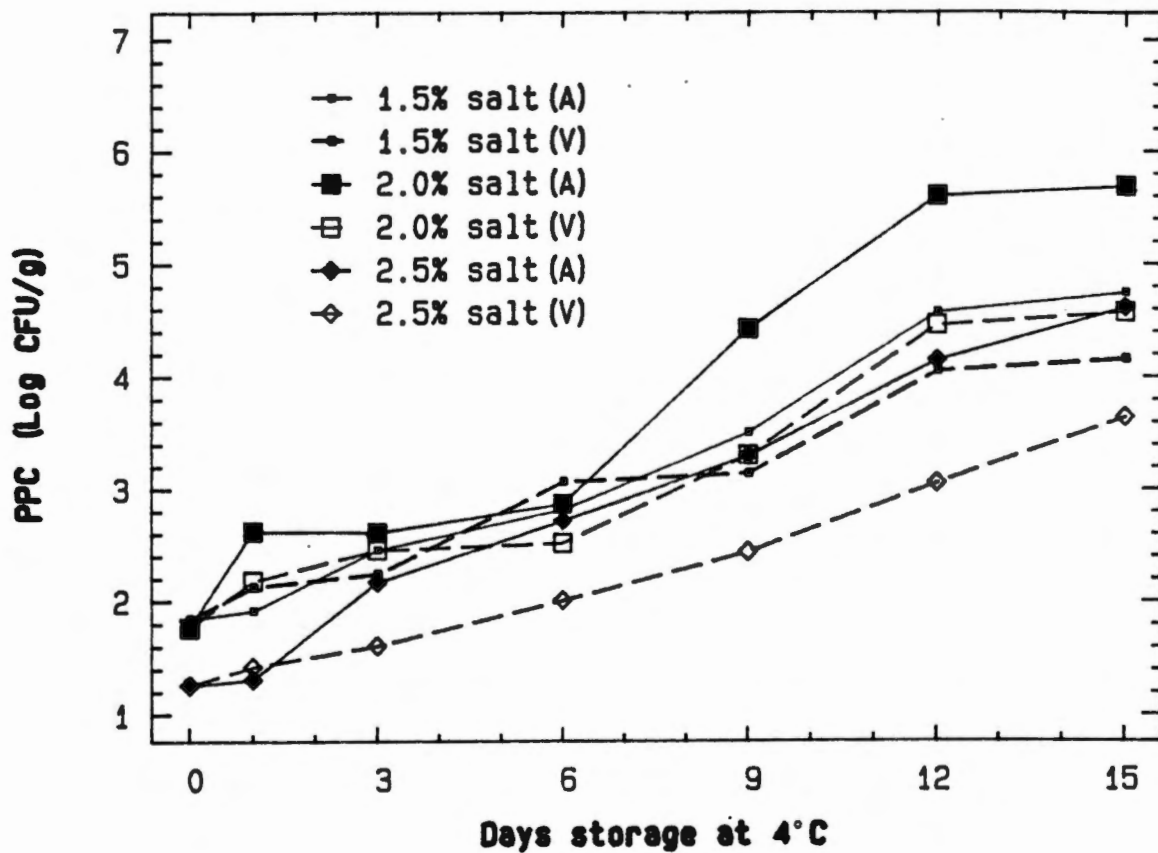


Figure 8. The growth curves of psychrotrophs in turkey hams with 1.5% to 2.5 % salt held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.

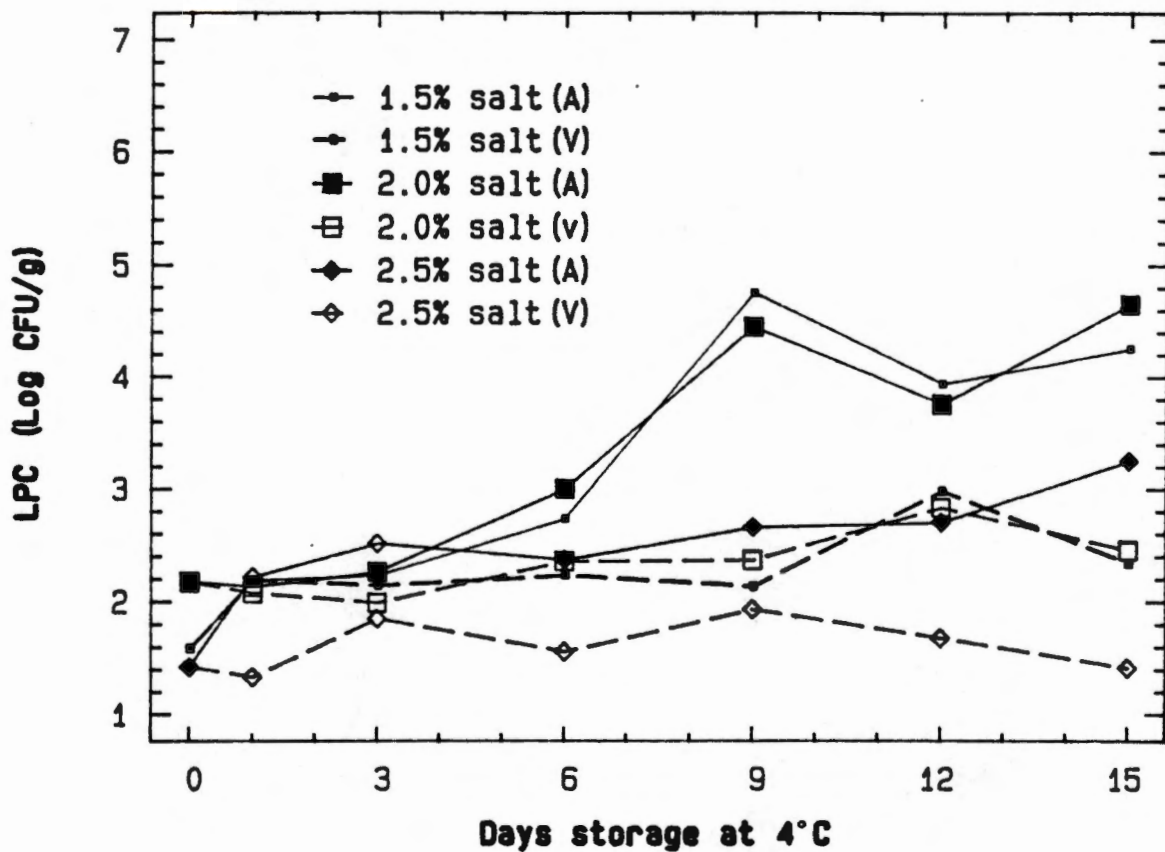


Figure 9. The growth curves of lactobacilli in turkey hams with 1.5% to 2.5 % salt held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.

Psychrotrophic plate count (PPC) was very low initially (Figure 8), but increased over 3 log CFU/g in hams containing 2.0% NaCl under aerobic packaging. All PPC per gram of turkey ham increased over the 15 day storage period, however, vacuum packaged hams had the smallest increase in PPC. Final levels of PPC/g ranged between log 3.6 CFU/g for 2.5% NaCl (vacuum) to log 5.7 CFU/g for formulations containing 2.0% NaCl (aerobic).

Growth of lactic acid bacteria (LPC) in turkey ham as a function of salt level is shown in Figure 9. Lactics initially ranged between log 1.4 and 2.2 CFU/g. Lactics increased rapidly in turkey hams containing 1.5% or 2.0% NaCl under aerobic packaging. However, LPC/g in formulation containing the higher salt content (2.5% NaCl) or stored under vacuum packaging remained fairly stable or even decreased slightly.

Overall effects of salt, salt and erythorbate and salt, erythorbate and STPP on growth of aerobes (APC), psychrotrophs (PPC), and lactobacilli (LPC) in hams formulated with each treatment are presented in Figures 10, 11, and 12. APC/g initially ranged from log 1.8 to log 2.6 CFU/g and increased to log 3.8 to log 5.2 after 15 days at 4°C. PPC/g was initially log 1.5 to log 1.9 CFU/g and increased rapidly from log 3.0 CFU/g to average log 5.2 CFU/g after 6-day storage in treatments containing salt and

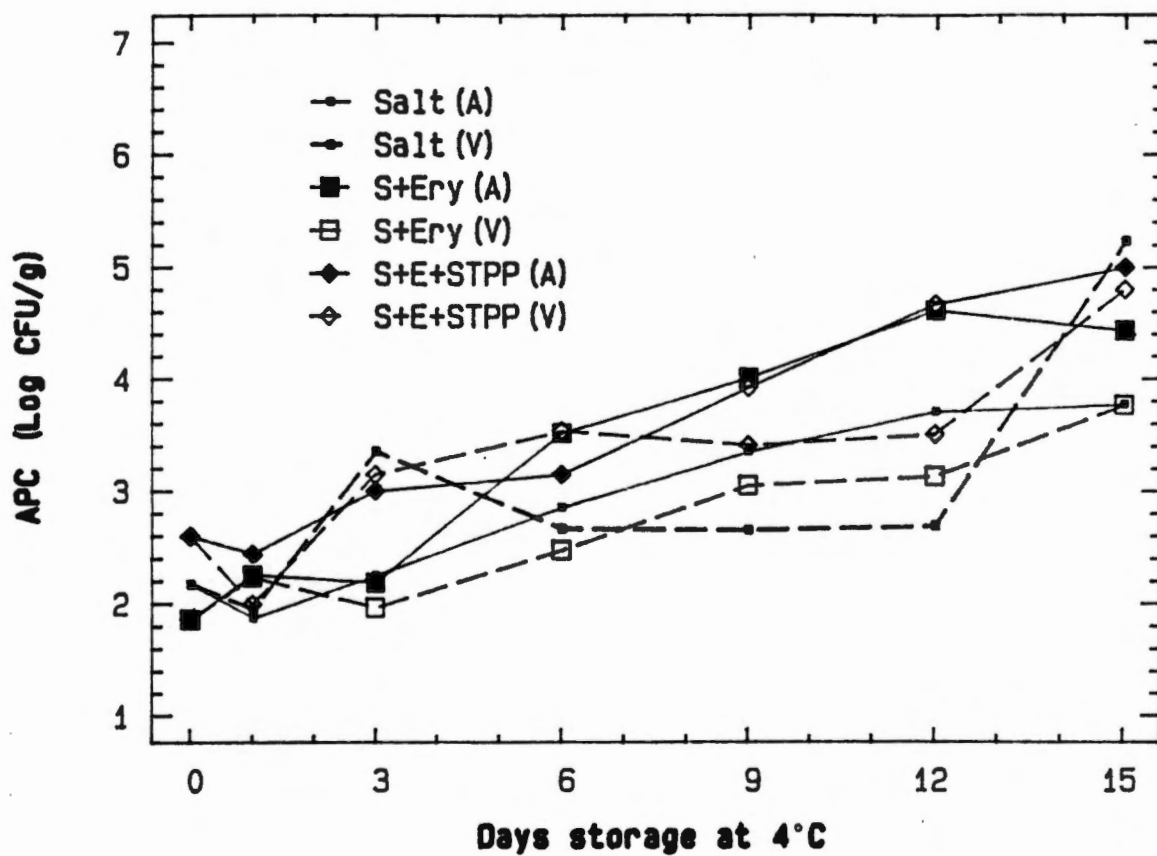


Figure 10. The growth curves of aerobes in turkey hams with salt (S), erythorbate (E), and STPP held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.

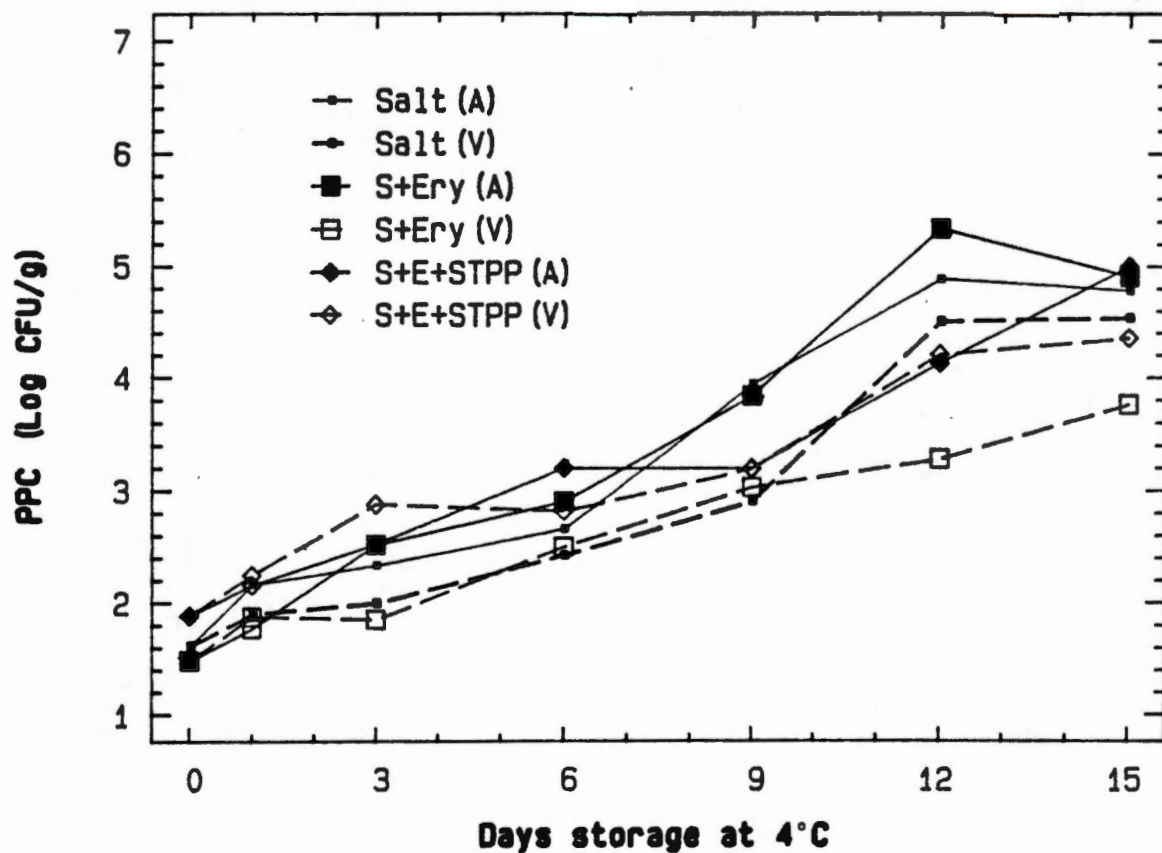


Figure 11. The growth curves of psychrotrophs in turkey hams with salt (S), erythorbate (E), and STPP held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.

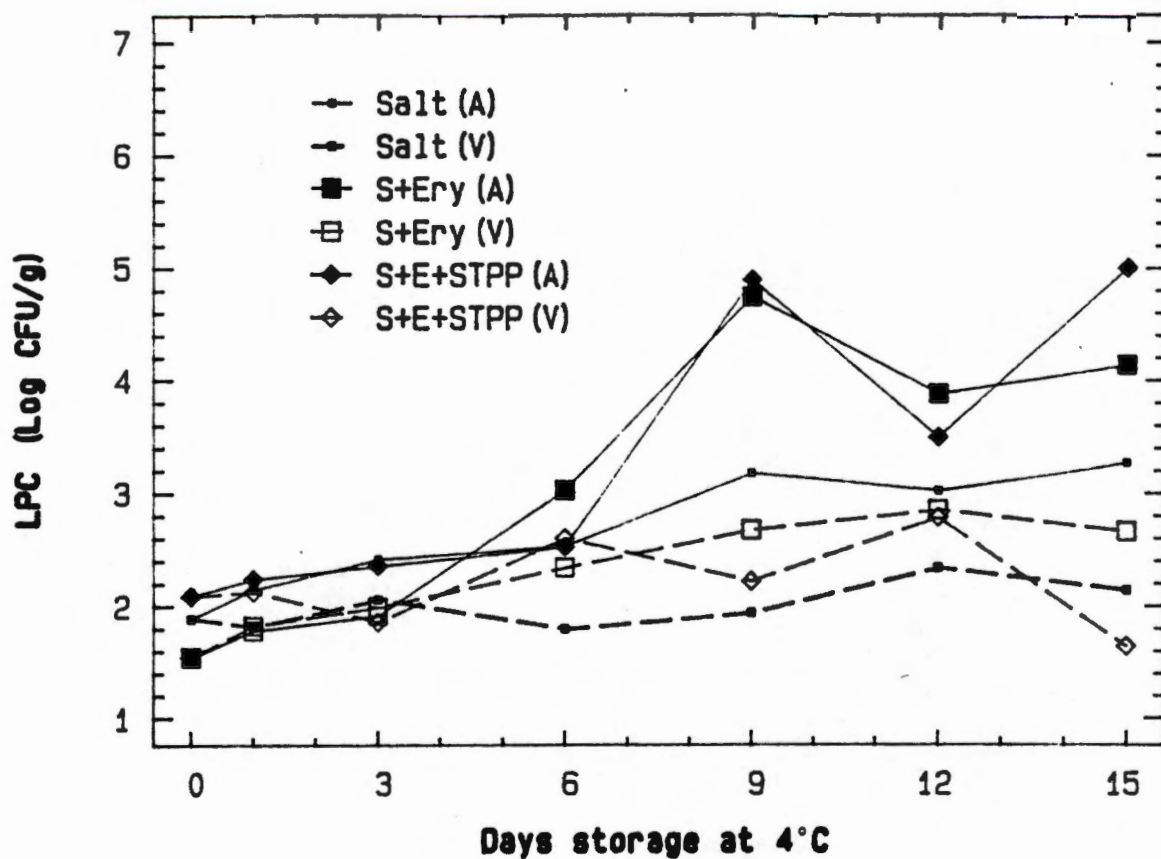


Figure 12. The growth curves of lactobacilli in turkey hams with salt (S), erythorbate (E), and STPP held at 4°C for 15 days under aerobic (A, solid line) and vacuum (V, broken line) conditions.

erythorbate under aerobic packaging. PPC/g ranged from log 3.8 to log 5.0 CFU/g after 15 days of storage at 4°C. LPC/g initially ranged from log 1.5 to log 2.1 CFU/g and increased to log 1.6 to log 5.0 CFU/g after 15 days at 4°C. In formulations containing erythorbate and STPP, LPC increased rapidly from log 2.1 CFU/g to log 5.0 CFU/g after 9 days of storage at 4°C under aerobic packaging. Although hams stored under vacuum packaging had the lowest counts, no significant differences ($p > 0.05$) were found when mean slope values of survival curves were analyzed (Table 13).

Table 13. Main effects of selected levels of salt, erythorbate, STPP on aerobes, lactobacilli, and psychrotrophs in vacuum and aerobically packaged turkey hams stored at 4°C for 0 to 15 days.

Treatment	Means Slopes		
	Aerobes	Lactobacilli	Psychrotrophs
Salt levels			
1.5%	0.141 a ^A	0.137 a	0.158 a
2.0%	0.178 a	0.094 a	0.230 a
2.5%	0.086 a	0.036 a	0.180 a
Erythorbate			
0	0.124 a	0.062 a	0.206 a
550 ppm	0.157 a	0.111 a	0.185 a
STPP ^B			
0	0.124 a	0.062 a	0.206 a
0.5%	0.124 a	0.093 a	0.177 a
Atmosphere			
vacuum	0.109 a	0.053 a	0.147 a
aerobic	0.160 a	0.125 a	0.231 a

^A Means within treatment groups followed by same letters are not significantly different ($p > 0.05$).

^B Also includes 550 ppm erythorbate.

CHAPTER V

CONCLUSION

Vacuum and aerobic packaging were not significantly different ($p > 0.05$) in inhibiting the survival of Salmonella. Salt levels of 2.5% and 3.0% were more inhibitory to Salmonella, aerobes, lactobacilli, and psychrotrophs than 0.5% to 2.0% in turkey ham held under vacuum packaging. Erythorbate and STPP in combination were more effective in preventing lipid oxidation of vacuum and aerobically packaged turkey hams held at 4°C than treatments containing only NaCl. From the standpoint of microbial safety and keeping quality, the best formulation for turkey hams held at 4°C was 2.5% salt, 550 ppm erythorbate, and 0.5% STPP under vacuum packaging. Viable Salmonella in turkey hams in this study persisted for 15 days at 4°C in vacuum and aerobic atmospheres. Since Salmonella decreased only slightly during storage of turkey hams, precautions must be taken to avoid Salmonella contamination while turkey hams are processed in commercial establishments.

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APPENDIX

Table A.1. ANOVA table on main effects for protein composition in turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	2	1.277	0.634	0.78	0.4996
Error	6	4.906	0.818		

Treatments ^a	2	0.318	0.159	0.159	0.8535
Error	6	5.865	0.977		

^aTreatments = salt, salt+erythorbate, salt+erythorbate+STPP.

Table A.2. ANOVA table on main effects for fat composition in turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	2	17.039	8.519	1.99	0.2169
Error	6	25.654	4.274		

Treatments ^a	2	16.821	8.411	1.95	0.2224
Error	6	25.863	4.310		

^aTreatments = salt, salt+erythorbate, salt+erythorbate+STPP.

Table A.3. ANOVA table on main effects for moisture composition in turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	2	44.290	22.145	1.02	0.4169
Error	6	130.781	21.797		

Treatments ^a	2	75.437	37.719	2.27	0.1843
Error	6	99.633	16.606		

^aTreatments = salt, salt+erythorbate, salt+erythorbate+STPP.

Table A.4. ANOVA table on main effects for ash composition in turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	2	1.057	0.529	11.62	1.0086
Error	6	0.273	0.045		

Treatments ^a	2	0.199	0.100	0.53	0.61493
Error	6	1.131	0.188		

^aTreatments = salt, salt+erythorbate, salt+erythorbate+STPP.

Table A.5. ANOVA table on main effects for TBA analysis on turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	2	7.073	2.358	20.53	0.0001
Error	121	13.895	0.115		

Treatments ^a	3	10.920	3.640	43.84	0.0001
Error	121	10.047	0.083		

Atmospheres	2	8.044	4.022	37.97	0.0001
Error	121	12.923	0.106		

Storage days	4	7.320	1.830	16.09	0.0001
Error	121	13.647	0.114		

^aTreatments = salt, salt+erythorbate, salt+erythorbate+STPP.

Table A.6. ANOVA table on main effects for TA analysis on vacuum packaged turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	5	0.1642	0.0324	0.56	0.7322
Error	12	0.7017	0.0585		

Erythorbate	1	0.0261	0.0261	0.40	0.5422
Error	10	0.6565	0.6565		

STPP	1	0.0007	0.0007	0.01	0.9119
Error	10	0.5246	0.0525		

STPP+Erythorbate	1	0.0184	0.0184	0.38	0.5524
Error	10	0.4869	0.0487		

Table A.7. ANOVA table on main effects for TA analysis on aerobically packaged turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	5	4.9246	0.9851	0.37	0.8625
Error	12	32.3263	2.6938		

Erythorbate	1	0.3422	0.3422	0.15	0.7122
Error	10	22.7642	2.276		

STPP	1	4.0832	4.0832	2.78	0.1258
Error	10	14.6694	1.4669		

STPP+Erythorbate	1	0.0867	0.0867	0.04	0.8532
Error	10	22.6533	2.2653		

Table A.8. ANOVA table on atmosphere effect for TA analysis on turkey hams.

Source	DF	SS	MS	F	PR > F
Atmospheres	1	1.823	1.823	1.63	0.2109
Error	34	38.115	1.121		

Table A.9. ANOVA table on main effects for pH analysis on vacuum packaged turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	5	5.1640	1.0331	0.84	0.544
Error	12	14.6703	1.2338		

Erythorbate	1	0.0072	0.0072	0.01	0.9435
Error	10	13.2802	1.3280		

STPP	1	1.0384	1.0384	0.70	0.4228
Error	10	14.8273	1.4827		

STPP+Erythorbate	1	0.8752	0.8752	0.97	0.3474
Error	10	8.9989	0.8999		

Table A.10. ANOVA table on main effects for pH analysis on aerobically packaged turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	5	172.39	34.48	4.63	0.0139
Error	12	89.42	7.45		

Erythorbate	1	21.277	21.277	0.92	0.364
Error	10	231.055	23.105		

STPP	1	9.828	9.828	0.70	0.4228
Error	10	100.653	10.065		

STPP+Erythorbate	1	2.168	2.168	0.15	0.7096
Error	10	147.605	14.761		

Table A.11. ANOVA table on atmosphere effect for pH analysis turkey hams.

Source	DF	SS	MS	F	PR > F
Atmospheres	1	137.494	68.747	8.11	0.0014
Error	34	279.828	8.479		

Table A.12. Mean TBA numbers^A of vacuum and aerobically packaged turkey hams held at 4°C for 0, 6, 12, and 15 days (Replication 1).

Treatment ^B	Vacuum Package				Aerobic package		
	0	6	12	15	6	12	15
0.5% S	0.260	0.312	0.620	0.483	0.314	0.603	NA ^C
1.0% S	0.189	0.272	0.303	0.499	0.369	0.289	NA
1.5% S	0.371	0.870	0.815	0.613	0.914	1.306	0.710
2.0% S	0.856	1.147	1.549	1.034	0.838	1.495	1.880
2.5% S	1.106	0.763	0.355	1.584	1.126	1.332	1.724
3.0% S	0.352	0.427	0.748	0.753	0.427	1.021	1.064
0.5%S+E	0.176	0.192	0.192	0.186	0.185	0.277	NA
1.0%S+E	0.284	0.696	0.569	0.878	0.383	0.350	NA
1.5%S+E	0.133	0.154	0.144	0.137	0.355	0.688	0.773
2.0%S+E	0.263	0.219	0.515	0.298	0.652	0.701	0.800
2.5%S+E	0.290	0.446	0.415	0.491	0.771	0.837	0.695
3.0%S+E	0.203	0.556	0.525	0.528	0.831	1.325	1.425
0.5%S+E+P	0.681	0.616	0.682	0.629	1.019	0.492	0.855
1.0%S+E+P	0.136	0.270	0.310	0.153	0.277	0.711	0.707
1.5%S+E+P	0.978	1.192	0.419	0.497	1.207	1.533	1.236
2.0%S+E+P	0.311	0.572	0.701	1.790	0.744	0.940	NA
2.5%S+E+P	0.624	1.128	1.204	1.119	1.145	1.131	0.864
3.0%S+E+P	0.595	0.789	0.609	0.764	1.264	1.009	0.890

^A TBA numbers = mg malonaldehyde/kg sample.

^B Not available due to the spoilage of sample.

^C S=NaCl, E=550 ppm erythorbate, and P=0.5% STPP.

Table A.13. Mean TBA numbers^A of vacuum and aerobically packaged turkey hams held at 4°C for 0, 6, 12, and 15 days (Replication 2).

Treatment ^B	0	<u>Vacuum Package</u>			<u>Aerobic Package</u>		
		6	12	15	6	12	15
1.0% S	0.780	0.390	0.468	0.390	0.858	0.468	0.468
1.5% S	0.468	0.624	0.390	0.546	0.702	0.468	0.780
2.0% S	0.585	0.702	0.624	0.624	0.546	0.780	0.858
1.5% S+E	0.234	0.468	0.312	0.234	0.468	0.390	0.390
2.0% S+E	0.156	0.390	0.312	0.156	0.312	0.312	0.156
2.5% S+E	0.351	0.156	0.234	0.234	0.468	0.234	0.234
1.5% S+E+P	0.117	0.078	0.156	0.156	0.156	0.156	0.156
2.0% S+E+P	0.234	0.312	0.156	0.078	0.234	0.156	0.390
2.5% S+E+P	0.117	0.156	0.234	0.078	0.156	0.312	0.234

^ATBA numbers = mg malonaldehyde/kg sample.

^BS=NaCl, E=550 ppm erythorbate, and P=0.5% STPP

Table A.14. Slopes of survival curves of S. blockley, S. infantis, and S. typhimurium in vacuum packaged turkey hams held at 4°C for 15 days.

Treatment ^B	Mean Slopes ^A (x 10 ⁻²)		
	<u>S. blockley</u>	<u>S. infantis</u>	<u>S. typhimurium</u>
0.5% NaCl	-3.03	2.17	-1.74
1.0% NaCl	-4.99	-5.31	-3.93
1.5% NaCl	-5.87	-8.66	-10.80
2.0% NaCl	-2.31	-1.37	-3.91
2.5% NaCl	-2.58	-7.17	-5.85
3.0% NaCl	-4.36	-6.36	-5.06
0.5% NaCl+E	-6.75	-7.44	-3.60
1.0% NaCl+E	-1.25	-6.32	-4.01
1.5% NaCl+E	-5.58	-6.02	-3.23
2.0% NaCl+E	-2.08	-2.22	-4.88
2.5% NaCl+E	-4.04	-2.99	-5.98
3.0% NaCl+E	-3.18	-6.71	-6.36
0.5% NaCl+E+P	0.31	0.90	-1.42
1.0% NaCl+E+P	-4.24	-1.22	-2.48
1.5% NaCl+E+P	-4.07	0.15	-5.52
2.0% NaCl+E+P	-3.34	-5.61	-5.90
2.5% NaCl+E+P	-6.12	-4.16	-4.68
3.0% NaCl+E+P	-11.50	-10.70	-3.32

^ANo significant differences ($p > 0.05$) among Salmonella strains in same treatment.

^BE=550 ppm erythorbate, and P=0.5% STPP.

Table A.15. Slopes of survival curves of S. blockley, S. infantis, and S. typhimurium in aerobically packaged turkey hams held at 4°C for 15 days.

Treatment ^B	Mean Slopes ^A (x 10 ⁻²)		
	<u>S. blockley</u>	<u>S. infantis</u>	<u>S. typhimurium</u>
0.5% NaCl	-7.20	12.37	-11.00
1.0% NaCl	-9.75	-17.50	-14.46
1.5% NaCl	-3.99	-9.46	-6.09
2.0% NaCl	-2.59	-1.09	-9.16
2.5% NaCl	-5.34	-6.72	-5.19
3.0% NaCl	-7.68	-9.91	-7.43
0.5% NaCl+E	-16.73	-25.72	-15.25
1.0% NaCl+E	-6.16	-11.21	-5.83
1.5% NaCl+E	-4.02	-5.96	-5.03
2.0% NaCl+E	-5.69	-8.97	-3.12
2.5% NaCl+E	-4.13	-6.95	-5.96
3.0% NaCl+E	-3.98	-12.94	-11.03
0.5% NaCl+E+P	-8.30	-7.40	-17.80
1.0% NaCl+E+P	-18.23	-16.95	-10.62
1.5% NaCl+E+P	-9.60	-5.51	-7.71
2.0% NaCl+E+P	-8.80	-4.94	-5.54
2.5% NaCl+E+P	-8.34	-7.95	-9.67
3.0% NaCl+E+P	-1.27	-12.60	-3.77

^ANo significant (p > 0.05) differences among Salmonella strains in same treatment.

^BE=550 ppm erythorbate, and P=0.5% STPP.

Table A.16. ANOVA table on main effects for the survival of Salmonella on vacuum packaged turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	5	99.804	19.9608	3.19	0.0146
Error	48	300.697	6.265		

Erythorbate	1	0.0633	0.0633	0.01	0.9190
Error	34	205.271	6.0345		

STPP	1	2.528	2.528	0.34	0.5629
Error	34	251.848	7.407		

STPP+Erythorbate	1	1.791	1.791	0.18	0.6739
Error	34	338.041	9.842		

Table A.17. ANOVA table on main effects for the survival of Salmonella on aerobically packaged turkey hams.

Source	DF	SS	MS	F	PR > F
Salt levels	5	269.078	53.82	1.50	0.2067
Error	48	1719.119	35.82		

Erythorbate	1	95.03	95.03	2.15	0.1519
Error	34	1503.99	44.235		

STPP	1	7.398	7.398	0.28	0.5985
Error	34	890.373			

STPP+Erythorbate	1	155.460	155.460	4.27	0.0465
Error	34	1238.173	36.412		

Table A.18. ANOVA table on atmosphere effect for the survival of Salmonella in turkey hams.

Source	DF	SS	MS	F	PR > F
Atmospheres	1	359.34	359.34	15.95	0.0001
Error	106	2388.70	22.54		

Table A.19. Mean slopes of aerobes, lactobacilli, and psychrotrophs in vacuum packaged turkey hams held at 4°C.

Treatment ^A	Mean Slopes ($\times 10^{-2}$)		
	Aerobes	Lactobacilli	Psychrotrophs
0.5% NaCl	15.02 ab ^B	20.33 ab	24.76 a
1.0% NaCl	31.82 ab	14.31 ab	30.35 a
1.5% NaCl	16.15 ab	2.95 b	18.86 a
2.0% NaCl	12.59 ab	5.78 ab	22.96 a
2.5% NaCl	2.94 ab	-1.55 b	12.26 a
3.0% NaCl	0.83 ab	0.36 b	21.05 a
0.5% NaCl+E	12.90 ab	12.91 ab	10.11 a
1.0% NaCl+E	42.62 a	17.53 ab	12.33 a
1.5% NaCl+E	9.75 ab	9.98 ab	12.29 a
2.0% NaCl+E	12.45 ab	1.80 b	11.72 a
2.5% NaCl+E	13.79 ab	2.68 b	19.15 a
3.0% NaCl+E	22.50 ab	5.63 b	9.61 a
0.5% NaCl+E+P	23.02 ab	4.14 b	29.13 a
1.0% NaCl+E+P	26.29 ab	33.16 a	29.71 a
1.5% NaCl+E+P	14.24 ab	4.16 b	10.90 a
2.0% NaCl+E+P	18.16 ab	2.74 b	13.40 a
2.5% NaCl+E+P	3.80 ab	1.35 b	10.94 a
3.0% NaCl+E+P	-8.69 b	1.71 b	20.44 a

^AE=550 ppm erythorbate, and P=0.5% STPP.

^BMeans in columns followed by same letters are not significantly different ($p > 0.05$).

Table A.20. Mean slopes of aerobes, lactobacilli, and psychrotrophs in aerobically packaged turkey hams held at 4°C.

Treatment ^A	Mean Slopes ($\times 10^{-2}$)		
	Aerobes	Lactobacilli	Psychrotrophs
0.5% NaCl	71.11 ab ^B	66.21 a	37.30 a
1.0% NaCl	80.91 a	55.70 abc	52.04 a
1.5% NaCl	14.41 bc	9.44 bcd	20.40 a
2.0% NaCl	25.14 abc	17.97 abcd	34.97 a
2.5% NaCl	3.01 c	2.84 cd	14.00 a
3.0% NaCl	17.84 abc	-5.03 d	20.28 a
0.5% NaCl+E	48.29 abc	59.40 ab	40.32 a
1.0% NaCl+E	50.86 abc	35.82 abcd	40.27 a
1.5% NaCl+E	17.29 abc	20.17 abcd	13.92 a
2.0% NaCl+E	26.37 abc	20.76 abcd	30.77 a
2.5% NaCl+E	13.12 bc	11.68 bcd	22.82 a
3.0% NaCl+E	24.72 abc	13.88 abcd	23.92 a
0.5% NaCl+E+P	29.50 abc	7.11 bcd	17.91 a
1.0% NaCl+E+P	48.51 abc	27.40 abcd	49.58 a
1.5% NaCl+E+P	12.54 bc	13.75 abcd	18.27 a
2.0% NaCl+E+P	17.67 abc	7.40 bcd	23.91 a
2.5% NaCl+E+P	13.37 bc	8.19 bcd	28.88 a
3.0% NaCl+E+P	14.20 bc	7.77 bcd	27.78 a

^AE=550 ppm erythorbate, and P=0.5% STPP.

^AMeans in columns followed by same letters are not significantly different ($p > 0.05$).

VITA

Cheng-An Hwang was born to Chin-Long and Lin-Po Hwang in Chiayi, Taiwan, R.O.C. on March 24, 1959. He graduated from the Department of Food Processing in Chiayi National Institute of Agriculture in June 1979. He entered National Chung-Shin University in September 1981, and received a Bachelor of Science in Food Science in June 1983. The following August, he started to work as a full time teaching assistant in the Department of Foods Science and Nutrition in Fu-Jen University. Two years later in September, 1986, he began graduate studies for a Master of Science degree in Food Technology and Science. The degree was awarded in May, 1989.