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EFFECTS OF INGREDIENTS ON THE SURVIVAL OF *CAMPYLOBACTER JEJUNI* IN PROCESSED TURKEY HAMS

A Thesis

Presented for the

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Degree

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Boyd J. Lee III

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DEDICATION

To my parents, Boyd and Joan Lee, without whom this paper would not have been.

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ABSTRACT

The effects of selected levels of sodium chloride (1.5-2.5%), sodium erythorbate and sodium tripolyphosphate (STPP) on the survival of two strains of Campylobacter jejuni and growth of spoilage bacteria were studied in vacuum and aerobically packaged turkey hams held at 4C. As salt levels increased, the survival of campylobacters decreased significantly ($P<0.05$). A salt level of 2.0% and 2.5% resulted in optimal inhibition of campylobacters. The highest salt level (2.5%) in combination with erythorbate and STPP significantly ($P<0.05$) reduced survival of campylobacters. Survival of C. jejuni under vacuum packaging was significantly greater ($P<0.05$) than under aerobic packaging. Aerobic packaging of sliced turkey hams containing 2.5% NaCl reduced C. jejuni from approximately $\log_{10}$ 6.0 CFU/g to below detectable limits within 6 days at 4C.

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CHAPTER I

INTRODUCTION

The human pathogen, Campylobacter jejuni, has been proven to be a common causative agent of acute bacterial gastroenteritis (14,62,100). The isolation of C. jejuni from patients with diarrhea has been found to equal or exceed the rates for Salmonella spp. and Shigella spp. (14,93). Campylobacters are frequently isolated from many types of food, the most common being those of animal origin, such as eggs, milk, beef, duck, pork, and poultry (14,36,37, 39,47).

The poultry industry is growing at an ever increasing rate as more and more people turn from red meat to poultry (75). This trend will probably continue. Cornell professor, Bob Baker, states "you can do anything with poultry meat that you can with red meat"; he further says, "there is no end to the products that can be made from poultry meat (2)." In 1987, poultry consumption surpassed beef consumption because poultry is relatively inexpensive and is perceived as healthy due to its low fat content. Even so, Campylobacter jejuni is fast becoming a problem for the poultry industry. Recent studies show that the prevalence of this organism in poultry ranges as high as 85% (21,41,72,101,129). Campylobacter is found in the normal intestinal microflora of poultry (14,28,106).

Ingredients such as sodium chloride, sodium nitrite, sodium polyphosphate and sodium erythorbate are termed non-protein food additives. Such ingredients are generally used in very low concentrations in restructured meat products, but have a tremendous effect on product quality. These ingredients are known to affect functional properties, flavor, and product stability (12,24,69,84,107). The functional properties affected by ingredients include water absorption, binding, color, and texture. Some ingredients also increase product stability by serving as antimicrobials or antioxidants.

Increased sodium intake has been shown to encourage development of hypertension (25,51,52,54,63,71,124). Although there is much evidence that body sodium is positively correlated to blood pressure, it is certain that other factors play a major role in the development of hypertension (25,52,63,124). Nevertheless, people perceive sodium as a major causative agent of hypertension. The percent of those who named salt or sodium as a cause of hypertension nearly tripled between 1977 and 1982 (52). Physicians recommend a decrease in dietary sodium intake. Due to public awareness and concern, there has been a steady increase in the development of low sodium products. In the U.S., food processors have taken significant steps to decrease the sodium content of many foods and to better inform the consumer (3). In 1984, the FDA ammended the

Food Labeling regulations to include sodium content (33).

Little work has been done on C. jejuni's response to sodium chloride. Doyle and Roman have shown how C. jejuni reacts to sodium chloride in brucella agar; at 4C, C. jejuni is sensitive to 1.0% or more NaCl, while 0.5% NaCl is needed to sustain growth (27). Doyle and Roman (27) also showed Campylobacter growth at 42C with 1.5% NaCl, but not with 2.0% NaCl. Abram and Potter (1) reported that at 42C C. jejuni grew at NaCl levels of 0 to 1%, but growth levels declined sharply with higher salt levels (1).

The purpose of this study is to determine the effects of the four nonprotein ingredients on growth and survival of Campylobacter jejuni in vacuum and aerobically packaged restructured turkey products held under refrigeration. Because the processed poultry industry has grown at such a tremendous rate, microbiology of turkey hams has had trouble maintaining pace.

CHAPTER II

REVIEW OF LITERATURE

A. CAMPYLOBACTER

Taxonomy

Due to Campylobacter's morphologic similarity with Vibrio cholerae, it was originaly classified as Vibrio fetus (91,102). However, there are major differences in biochemical and growth characteristics and in mol % G + C content between true vibrios and the campylobacters (91,102). In 1973, in light of the above differences, two French scientists, Veron and Chatelain, suggested that the group classed as Vibrio fetus be reclassified as a new genus Campylobacter (91,68). The name "Campylobacter" is derived from the Greek, meaning "curved rod".

There has been some controversy and confusion about the nomenclature and classification of strains within the Campylobacter genus. Bergey's Manual of Systematic Bacteriology shows the current accepted version of species and subspecies of the genus Campylobacter (68).

Taxonomic problems arise in distinguishing between C. jejuni and C. coli and in determining if C. sputorum subsp. mucosalis is a separate species of Campylobacter. The hippurate hydrolysis test is the most reliable method to distinguish between C. jejuni and C. coli (50). C.

sputorum subsp. mucosalis is the only C. sputorum subspecies which requires hydrogen and oxygen for growth. Because of this unusual gaseous atmospheric requirement, there is a question as to whether C. sputorum subsp. mucosalis should be a separate species (68).

Morphology

Campylobacters are gram negative, spirilla or vibrios 0.5-5.0 µm long by 0.2-0.5 µm wide. Cells may have one curve or twist or may be S shaped (62,91,100,102). Coccoid forms emerge in old cultures (91,100,102). Studies show that coccoid forms are a degenerate stage produced by unfavorable growth conditions (17,102), such as crowded plates or when the growth medium becomes too alkaline (pH 8.5-9.0). Loss of cellular integrity and dissolution of the cell envelope produces the rounded morphology (17). Old cultures composed mainly of coccoid forms are generally nonviable (102). The ends of the cells are usually tapered but C. fetus ssp. fetus are usually more blunt-ended than the jejuni/coli group (100).

Campylobacters are motile with a characteristic corkscrew movement (14,102,111). Cells move across a microscopic field darting, twirling or rotating in a spiral motion. They can have a single flagellum at one or both ends (99,100) with C. pylori exhibiting four flagella at one pole (117). Early log-phase cultures are highly motile,

mature cultures are less actively motile and old coccoid cultures can be motile or nonmotile (100).

Observing C. fetus by electron microscopy shows an outer cell membrane that is double layered and loosely fitting over the cell wall. The cell wall has three layers with an outer lipoprotein layer, a middle lipopolysaccharide layer, and an inner mucopeptide layer.

When incubated for 48 hours at 37C on culture media, C. fetus ssp. fetus strains produced small, round and convex colonies that grew up to 2mm in diameter. Atypical strains produced similar colonial types, but three atypical strains produced a lemon-yellow pigment and two others caused greening of blood agar. Colonies of the jejuni/coli group were typically flat, low convex, glossy and effuse; many strains showed swarming on moist agar. Mature cultures of C. jejuni-like strains developed a metallic sheen; this characteristic was absent or much less apparent with C. coli-like strains (100). Colony appearance differs with the type of culture medium; however, smooth, convex, translucent, colorless to cream-colored, nonhemolytic, and pinpoint to 2 to 4mm diameter colonies are typical of Campylobacter (13,91).

Growth requirements

Campylobacters are microaerophilic organisms (13,14,16,38,43,53,74,82,100,102,125) which have optimal

growth when 5-6% oxygen is present (14,38,91,102,114). Campylobacters grow in an oxygen concentration between 3 and 15% and a carbon dioxide concentration of 3-5% (68). Normal oxygen concentrations are lethal (38,43,125), but a few strains may grow slightly under aerobic conditions (20% oxygen) (68). An atmospheric mix of 5:10:85 O_2:CO_2:N_2 is most commonly used to incubate Campylobacter cells. C. concisus requires 10-85% hydrogen while C. sputorum ssp. mucosalis requires 97% hydrogen and 3% oxygen (68). C. sputorum is a strict anaerobe (91).

C. jejuni/coli grows best when incubated at 42C (14,50,68,111), but this temperature will not support the growth of C. fetus which requires an incubation temperature of 37C (68).

Campylobacters are chemoorganotrophs which neither ferment nor oxidize carbohydrates (68). A chemoorganotroph is an organism which obtains energy from oxidation-reduction reactions with an organic carbon source. The primary energy sources for campylobacters are amino acids and Kreb's (tricarboxylic acid) cycle intermediates (62,68).

Campylobacters do not require blood for growth. Gelatin and urea are not hydrolyzed (68).

B. CAMPYLOBACTER ENTERITIS

Before Campylobacter was recognized as one of the leading causes of human gastroenteritis, it was believed to

be a concern only in animals. According to Karmali and Fleming (62), McFadyean and Stockman were the first to report the relationship of these organisms with ovine and bovine abortion in 1913. In 1918, the relationship was confirmed when Smith found similar organisms in aborted bovine fetuses (62). A problematic disease in cattle known as winter scours or winter dysentery was connected with microaerophilic vibrios in 1913. The disease would cause diarrhea and decreased milk production in just a few cows and eventually spread throughout the herd; the affected animals had blood and mucus in their stools, and some animals showed signs of abdominal distress (62). Winter scours in cattle resembles campylobacter enteritis in humans. In 1947, the first proven case of human campylobacter infection was reported (91). It was not until 1971 that campylobacters were successfully isolated from a stool sample (62). Of the patients requiring medical attention in developed countries, 3 to 14% had C. jejuni isolated from their stool samples (14). In developing countries, it is not uncommon for C. jejuni to be isolated from healthy persons (14).

Recently there have been an increasing number of reports implicating campylobacters as causative agents in approximately 5% of cases involving acute gastroenteritis. C. jejuni/coli are the two strains which commonly cause human gastroenteritis (14,62,91). C. fetus ssp. fetus may

also cause human gastroenteritis (91).

Predisposing conditions which are associated with this infection are immunosuppressive therapy, alcoholism, cardiac disease, liver disorders (44,62,91), diabetes, leukemia, lymphoma, splenectomy, tuberculosis (91), and malnutrition (62). Campylobacter has probably always been a major cause of human gastroenteritis but now with a more thorough understanding of Campylobacter, researchers know how to look for this organism. At present, Campylobacter is one of the leading causes of gastrointestinal infection in humans (14,62,81,100), but the route and source of human infection remains a question (44,62,91). The incubation period for campylobacter enteritis in humans is 2 to 5 days (43,62).

Characteristics of infection

Clinical signs of campylobacter enteritis are fever, abdominal pain and often diarrhea (14,15,43,44,62,91). Mucus containing stools are often present (62). Fever, 38C to 40C, appears within a day or two and follows a relapsing or intermittent course (91). Fever is associated with malaise, headaches, musculoskeletal pain, delirium (43,62,97), and sometimes paralysis (44,62).

Diarrhea is usually mild to moderate, but may be excessive, watery and frequent (62). A few days after the onset of the disease, bloody stools can develop (14,15,44,62). In one case study, Blaser et al. (15) showed

that only 7% of the afflicted persons had a grossly bloody stool, which is a much lower percentage than hospital-based studies. They explain the difference as a hospital selection bias; patients with symptoms severe enough to warrent a stool sample are possibly those with the most severe illnesses.

Central nervous system symptoms of confusion and sluggishness are not uncommon (44,91). Although vomiting and dehydration are not normal symptoms, both have occurred in some cases (43,62). A cough may or may not develop (91).

Symptom duration varies but usually lasts 2-7 days (14,15,43,62). Karmali and Fleming (62) reported that abdominal pain can last up to six weeks with the illness persisting and relapsing. Blaser et al. (15) also investigated gastroenteritis cases in which symptoms lasted longer than one week, but most symptoms were over in two days. Although death is rare, fatalities have been reported (43,62,91).

Reservoirs

Animal-to-human contact, person-to-person contact, and consumption of contaminated water or food have all been cited as possible sources of human campylobacter enteritis (43,44).

Campylobacters are common inhabitants in a wide variety of animals (14,43). Many animals carry Campylobacter

around as normal intestinal microflora (14). Campylobacter has been cultured from poultry, including ducks (14,43,55,61, 67,72,80,81,83,91,112,113,122), beef (14,36,39,47,80,110, 112), pork (14,47,80,110,112), lamb (39,47,109,110,112), dogs (91), seagulls (100), and milk (62,88). Food animals infected with Campylobacter can pose a possible contamination threat to the public. In Vermont, a large outbreak of campylobacter enteritis was assumed to be from a water-borne source (91). Infected mothers have been known to infect neonates (91). Therefore, Campylobacter transmission can follow many routes.

C. SALT

Nonprotein food additives, like salt, are generally used in low concentrations in restructured meat products but have important effects on product quality (84). Salt, as well as other nonprotein additives, has several useful functions such as affecting functional properties, flavor, and product stability (9).

The major salt used in restructured meat products is sodium chloride. Although other salts, magnesium and potassium chloride, are available and have similar effects on functional properties, they can be toxic and/or produce off-flavors (84). Hand et al. (46) found that sodium chloride and potassium chloride showed no major differences in their effects on texture of restructured pork roast.

Using a 30% mixture of KCl salt with NaCl had no effect on palatibility or microbial quality, while replacing 50% of the NaCl severely decreased palatability and increased microbial numbers (70). Other researchers have found that 50/50 KCl/NaCl gave the best physical bind and acceptable sensory scores (34). Magnesium chloride and potassium chloride are generally recognized as safe (GRAS) and require USDA approval before they can be used.

The functional properties of meats which are affected by salt are water-binding ability (84,128), color, and most importantly, texture, specifically the cohesion between the meat pieces (84). Texture and water-binding are highly correlated (79,120). According to Schmidt et al. (97), salts improve the functional properties of meats in two ways. First, the negative chloride ions increase water uptake by binding to the muscle tissues. These negative charges force the myofilaments apart forming a strong three-dimensional matrix allowing more room for water thus decreasing cooking loss (24,69,128). Second, the salts aid in the extraction of salt-soluble protein so that it is available at the meat surface forming a tacky layer which binds pieces together. Generally, the combined use of salt (1-3%) and sodium polyphosphate (0.25-0.50%) has produced even greater changes in texture than either additive alone (24,69,84,128). In restructured poultry, pork, veal, and lamb, salt concentrations do not appear to be as crucial in

maintaining textural properties as they do in beef products (84). Added salts can aid in binding by means other than protein extraction. Salts can cause pH changes and protein-ion interactions, both of which are believed to be involved with binding (84).

Flavor can also be affected by salt. Hammer (45) states that salt concentrations below 1.0% will not improve flavor while concentrations above 2.0% produce a salty flavor. Since there are no restrictions on the amount of salt added to restructured products, flavor usually plays the determining role in selection of salt concentrations.

At higher concentrations, salts can act as antimicrobials in meat products. However, due to uneven distribution in restructured meat products, salts may not serve well in that capacity. Ayres et al. (8) states that at 3.0 to 5.0% salt, most bacteria and yeast are inhibited. The shelf life of fish fillets can be greatly extended by dipping the fish muscle in a 5% NaCl solution for one minute and then sealing in a CO_2 flushed bag (77). Barbut et al. (9) proved that increasing NaCl content from 1.0 to 3.0% delayed *Clostridium botulinum* toxin production an average of three days. Although a medium containing 3.5% NaCl inhibits the growth of *Campylobacter jejuni* (103), a reduced temperature, like that in a refrigerator, can reduce the injurious effect of the salt (27,48). Certain bacteria, termed halophiles, require salt in order to grow. Fifteen

percent salt is required for extreme halophiles, but they thrive on 25-30% salt. Moderate and light halophiles grow best at 5-20% and 1.5-5% NaCl, respectively (8).

Though beneficial in many ways, salts can pose problems in restructured meat products if not properly used. Sodium chloride can reduce consumer acceptance by causing increased myoglobin and lipid oxidation (69,84,104) and increased dietary sodium intake (60). Salts containing metal ions can cause an increase in autooxidation (105). Both types of oxidation increase progessively with NaCl concentration (84). Lipid oxidation yields a rancid off-flavor while myoglobin oxidation yields changes of color. Salt increases the potential for myoglobin oxidation by decreasing buffering capacity of meat. Salt also aids in lowering oxygen tension in meat which leads to pigment oxidation (84). Salt concentrations above 1.5% can decrease color desirability (84). Processed meat products provide approximately 15% of the total estimated dietary sodium intake (60). A high dietary sodium intake has been shown to contribute to hypertension which can lead to heart disease and/or renal failure (5,25,86). Thus, products with low sodium content are becoming popular among consumers (3). Magnesium and potassium chloride are currently being considered as partial substitutes.

D. NITRITE

Nitrite, a curing agent in meat products, can act to stabilize the color and flavor of meat as well as reduce oxidation and restrict some bacteria. Generally a finished product cannot contain in excess of 200 parts per million (ppm) residual sodium nitrite (56). Of the nitrite added to meat for curing purposes, less than 50% can be accounted for in the finished product (18). The nitrite restriction was set forth by the U.S. Department of Agriculture because 90% of the more than 300 nitroso compounds tested in laboratory animals caused cancer.

The major problem with nitrosamines in processed meats is the formation of N-nitrosopyrrolidine during bacon frying. Sodium ascorbate at 550 ppm together with 120 ppm sodium nitrite will substantially reduce nitrosamines in cured, cooked bacon (85). The Delaney Amendment of the Pure Food and Drug Act states that any food additive causing cancer must be removed from the food supply. It is generally accepted that risks from low levels of nitrosamines are less than those from botulism poisoning, which is a possibility if nitrites were removed from the cure.

Nitrite reduces color inconsistencies. The cured meat color formed upon cooking, is a stable pink color resulting from nitrite reacting with meat pigments (56). Two processes are involved in cured meat pigment formation: 1)

biochemical reactions in which nitrite is reduced to nitric oxide and iron in heme is reduced to the ferrous state, and 2) thermal denaturation of globin (32).

A characteristic flavor is also developed as either a direct result of nitrite or from nitrite retarding oxidative-type off-flavors. The desirable cured flavor appears to be directly related to an intense cured flavor and a less rancid flavor and not due to a lack of oxidized flavor (90). With some cured products, like salami and bacon, nitrite does not seem to be so clearly related to flavor (19). According to Cho and Brarzler (20), sodium nitrite contributes to the cured flavor along with salt, sugar and smoke in pork.

Nitrite delays the development of oxidative rancidity (123). Igene et al. have shown that nitrite may inhibit oxidation by three possible mechanisms: 1) by complexing with the iron heme keeping it in the reduced (Fe^{++}) state, thereby preventing the release of ferrous iron (Fe^{+++}) which is active as a catalyst of the propagation stage of lipid oxidation, 2) by stabilization of the unsaturated lipids within the membranes, and 3) by binding metal ions, such as ferrous ions, thus making them unavailable for catalysis of oxidation reactions (59).

Nitrite is an effective antimicrobial against Clostridium botulinum. Pivnick et al. showed that nitrite concentration was directly related to the delay in toxin

production and spoilage by C. botulinum (87). To control C. botulinum naturally occurring in meat and poultry or introduced by slaughter or processing, sodium nitrite must be added at 100 to 150 ppm (19). However, when luncheon meat was stored at 80F, a 156 ppm sodium nitrite addition was ineffective in inhibiting the germination of spores (19). Although nitrite is required for safety, other factors like salt level, pH, spore concentration and heat treatment undoubtedly play a contributing role (56).

E. PHOSPHATE

Phosphates, like salt, are considered nonprotein food additives and are added to meats in low concentrations. A level of 0.5% is the legal maximum phosphate content in a finished product (121). Phosphates at greater than a 0.3% level produce a harsh metallic flavor that can be undesirable to consumers; this flavor is not as bad with potassium phosphate (84). Functional properties of most restructured products will not be adversely affected if the phosphate level is reduced to 0.2 to 0.3% (84). There is 0.1% naturally occurring phosphate in muscle tissue which must be considered when using phosphates (94). The maximum addition which phosphate can be added in a restructured product is 0.125% (84).

The following phosphates are allowed in meat products: disodium phosphate, monosodium phosphate, sodium meta-

phosphate, sodium polyphosphate, sodium tripolyphosphate, sodium pyrophosphate, sodium acid pyrophosphate, dipotassium phosphate, monopotassium phosphate, potassium tripolyphosphate, and potassium pyrophosphate (94). All are sodium or potassium salts of phosphoric acids and are made up of phosphate units joined together. When one, two or three hydrogen ions on a phosphate unit are replaced by sodium or potassium ions, the resulting phosphate is termed sodium (potassium) , disodium (potassium) , and trisodium (potassium) phosphate, respectively (84). Potassium phosphates are not used much because they are hygroscopic which makes working with them difficult (84). Pyrophosphate increases functional properties of restructured meat products the greatest followed by tripolyphosphate, then tetrapolyphosphate, hexametaphosphate and orthophosphate increase functional properties least (84,119,120). Although phosphates do not increase functional properties when the sodium chloride concentration is below 0.8%, or greater than 2.0% or between 1.25-1.50% if the pH of the product is high (>6.0-6.3) (119), they do increase functional properties in products where the salt concentration is insufficient to extract salt-soluble proteins (9).

Phosphates increase the functional properties of restructured meat products much more than salt and stabilize the rate of color and flavor deterioration (84,95). Phosphates solubilize proteins by increasing the pH

(24,58,69,78,119), act as antioxidants (56,67,122) and improve water binding ability (24,58,69,78,119,128).

Through the color and flavor stabilization effects, phosphates increase storage life of frozen and precooked restructured meat products (84). This is achieved by decreasing the rate of pigment (mainly myoglobin) and lipid oxidation (58,84). Increasing the pH above 6.0, greatly reduces the rate of lipid and myoglobin oxidation (127). Phosphates prevent oxidation by sequestering and chelating heavy metal ions (118). Tripolyphosphates somewhat counteract the detrimental effect which sodium chloride has on color (23).

The exact reason phosphates improve functional properties more than salts is not fully understood, although increase in pH can explain part of the improvement (119, 84). Trout and Schmidt (119) state that approximately 80% of the increased binding ability was due to the increase in ionic strength and pH.

F. ASCORBATES

Ascorbates, commonly known as vitamin C, are utilized in the meat industry to speed up the cure process and color development of meat products. Quickening the color reaction is a result of the ascorbate reacting with the nitrite to produce more nitric oxide or reduce metmyoglobin to myoglobin (94). Ascorbic acid, sodium ascorbate,

erythorbic acid, and sodium erythorbate are the ascorbates approved by the USDA for curing pork and beef (89). Sodium erythorbate is usually the ingredient of choice due to its low cost. By federal regulation ascorbates can be added at a level of up to 550 ppm.

In addition to its beneficial effects on color, there is evidence that ascorbates and erythorbates decrease the rate of formation on nitrosamines in cured meat products (76). The formation of carcinogenic N-nitroso compounds produced by the reaction of residual nitrite with secondary and tertiary amines in cooked meats have been shown to be blocked by ascorbate and erythorbate.

G. VACUUM PACKAGING

According to Genigeorgis (35), vacuum packaging can be defined as the packaging of a product in a high-barrier package from which air is removed to prevent growth of aerobic spoilage organisms, shrinkage, oxidation, and color deterioration. Normally 10-20% carbon dioxide is produced by bacteria within vacuum packages as microorganisms on the food consume residual oxygen (99). This carbon dioxide can inhibit bacterial growth as would added carbon dioxide.

Although gram-negative organisms have been shown to cause spoilage of fresh, refrigerated red meats under aerobic conditions (65), the gram-positive, facultatively anaerobic, lactic acid producing bacteria like Lactobacillus

spp., Micrococcus spp., and Streptococcus spp. become predominant under conditions of reduced oxygen availability (30,31). Brochothrix thermosphacta and fermentative gram-negative bacteria have also been shown to survive in vacuum packaging (42). Vacuum packaging dry packed broilers showed significantly lower bacterial counts and a longer shelf life than poultry packed in air (66). C. jejuni has been shown to survive for long periods of time on processed turkey at 4C under vacuum packaging (68), and during refrigerated and frozen storage of poultry and beef liver (47). The shelf-life of fresh meat can be extended by gas-impermeable packaging in a vacuum (6,49,87).

Exclusion of oxygen from cured meat products through vacuum packaging can prevent oxidative rancidity and the oxidation of myoglobin (6). Vacuum packaging can also help eliminate weight loss (64).

CHAPTER III

MATERIALS AND METHODS

A. HAM FORMULATION

Nine turkey hams were formulated with ingredients as shown in Table 1. The turkey roll seasoning, sodium tripolyphosphate (STPP), and sodium erythorbate were obtained from Flavorite Laboratories, Inc (Memphis, TN). Superior evaporated granulated salt was obtained from the Diamond Crystal company (St. Clair, MI). Sodium nitrite was obtained from Sigma Chemical Co. (St. Louis, MO).

Eight pound hams were formulated using 90% thigh meat and 10% skin. Raw, frozen turkey meat and skin were obtained from Harrison's Chicken City (Knoxville, TN).

The thigh meat was ground through a 1 inch plate. The skin was chopped, with a small amount of meat and crushed ice, until smooth. The crushed ice was added at 12% of the total meat and skin weight. At the chopping stage, one-half of the salt and other spices were added. The temperature was kept at 45F (7.2C) or below.

The meat was mixed with the remaining ingredients at low speed for two minutes. The skin emulsion was added to the meat mixture and mixed until uniform (about 5 minutes). If STPP was in the formulation, it was dissolved in approximately 50 ml warm water prior to using; as little

Table 1. Formulation[a] and ingredient levels of nine turkey hams.

Sodium chloride %	Sodium erythorbate[b] ppm	Sodium tripolyphosphate %
1.5	0	0
2.0	0	0
2.5	0	0
1.5	550	0
2.0	550	0
2.5	550	0
1.0	550	0.5
1.5	550	0.5
2.0	550	0.5

[a] All turkey hams contained 156 ppm nitrite and 0.3125% turkey seasoning.

[b] ppm = parts per million.

water as possible was used. The meat mixture was then stuffed into a fibrous type casing.

The ham chubs were smoked using the schedule in Table 2. The hams were cooked to a minimum internal temperature of 165F (74C), removed and placed in an ice water bath overnight to cool.

B. BACTERIAL STRAINS

Two strains of C. jejuni were studied: ATCC 29428 (American Type Culture Collection, Rockville, MD), and CJ-B4086 (obtained from N.A. Cox, Richard B. Russell Agriculture Research Center, Athens, GA). The cultures were maintained in brucella broth with 0.1% agar and were transferred every week. Cultures were incubated at 42C for 48 hours with the following premixed atmosphere (MG Industries, Vally Forge, PA): 5% oxygen, 10% carbon dioxide and 85% nitrogen (OCN). Cultures were stored at 4C until needed.

C. INOCULUM PREPARATION

To prepare Campylobacter for inoculation, a 24 hour culture was prepared. Approximately 10 ml of a 48 hour culture, in brucella broth (with 0.1% agar), was poured into a 250 ml Erlenmeyer flask containing 100 ml of brucella broth (with 0.1% agar). A 1 ml tuberculin syringe was inserted through a number 6 one hole rubber stopper. Tubing was used to connect the syringe and a Gelman bacterial air

Table 2. Cooking schedule for turkey hams.

Cooking cycle	Wet bulb	Dry bulb	Damper
45 min.	98F (36.5C)	100F (37.5C)	closed
90 min.	128F (53.3C)	130F (54.5C)	closed
90 min.	158F (70.0C)	160F (72.0C)	closed
final cook	173F (78.2C)	175F (79.5C)	closed

filter (no. 4210). The flask containing the inoculum was evacuated and then flushed with OCN gas; this was done twice to ensure the proper atmosphere. The inoculum was incubated at 42C for 24 hours.

D. PREPARATION OF TURKEY SAMPLES

After formulating and freezing the hams of the first replication, 4 months passed before the hams were sliced into approximatly 10 g slices. The hams were refrozen until ready to use. Hams for the second replication were sliced the day after preparation, then frozen.

Two days prior to using, the ham was thawed at 4C. Ten gram turkey samples were then weighed into Steward medical Stomacher 400 bags (Tekmar Co., Cinncinatti, OH) and onto 5x5x1 inch (12.70x12.70x2.54 cm) polystyrene foam trays (Mobile Chemical Co., Covington, GA) which contained a sterile filter paper. The samples were either left untreated as controls or were inoculated with 0.1 ml of the appropriate 24 hour old Campylobacter inoculum culture. Inoculum was placed into a meat fold to prevent evaporation.

After inoculation samples to be vacuum packaged were placed in Stomacher bags and vacuum packaged using a Cryovac Multivac (Model #68/AG4/149). The stomacher bags were then vacuum sealed twice, in 8x16 inch (20.32x40.64 cm) standard gauge clear Cryovac barrier bags (oxygen transmission, 30-50 cc @22.7C (m^2, 24 hours, 1 ATM)). The polystyrene foam

trays were overwrapped with Reynolds 910 foodservice PVC film (Richmond, VA) (oxygen transmission, 150 cc($0.25\ m^2$, 24 hours, 1 ATM)). The samples were stored at 4C until enumeration and chemical test were performed.

E. MEDIA

Enumeration of aerobic plate counts (APC), psychrotrophic plate counts (PPC), lactobacilli plate counts (LPC), and Campylobacter plate counts (CPC) was done on storage days 0, 1, 3, 6, 9, 12, and 15. Bacto Plate Count Agar (Difco, Stone Mountain, GA) was used for SPC and PPC. APT Agar (BBL, Stone Mountain, GA) was used for the LPC, Campylobacter Blood-Free Selective Agar Base (Oxoid, Columbia, MD) containing Cefoperazone Selective Supplement (Oxoid) was used for CPC. 2, 3, 5-triphenyl tetrazolium chloride (TTC) was added to all agar at 0.01% to aid in enumeration.

Peptone (Difco) water was used as a diluent for SPC, PPC and LPC. Modified Cary-Blair Transport medium with 0.1 % agar (Appendix 1) was used as a diluent for campylobacters. Bacto Brucella Broth (Difco) was both a growth medium and enrichment medium for Campylobacter. The enrichment medium had Blazer-Wang selective supplement added (Oxoid).

F. ISOLATION PROCEDURE

The 10 g vacuum packaged turkey sample in the Stomacher bag simply had the top cut off the bag and the appropriate diluent added. The aerobically packaged samples were removed from the tray with sterile forceps, placed in a stomacher bag, and then the diluent added. The stomacher bags were placed in a Stomacher Lab Blender 400 and stomached for 2 minutes. Campylobacter (CPC) and the psychrotrophs (PPC) were spread plated while the aerobes (APC) and lactics (LPC) were pour plated.

The CPC plates were incubated at 42C for 3 days in a Gas Pak anaerobe jar (BBL) using a Gas Generating Kit (Oxoid) to obtain the desired OCN atmosphere. SPC plates were incubated at 32C for 2 days, the PPC plates at 7C for 10 days and the LPC plates at 35C for 3 days.

G. ENRICHMENT FOR CAMPYLOBACTERS

Using sterile forceps, the slice of turkey was removed from it's treatment container (tray or stomacher bag) and placed into a 250 Erylenmeyer flask containing the enrichment broth (see media). A sterile filtering apparatus was attached (see inoculum preparation) and OCN atmosphere was flushed into the system after a vacuum had been pulled. The system was flushed twice. The enrichment flask was incubated in static culture at 42C for 24 hours.

H. CHEMICAL TEST

Proximate composition

The frozen sample was powdered in a Waring blender for all proximate composition analyses. All methods for proximate analyses were AOAC (4). Nitrogen analyses was by AOAC 24.027 (4). Fat analyses was AOAC 24.005 (4). Moisture analyses was by AOAC 24.002 (4). Ash analyses was by AOAC 24.009 (4).

Salt (NaCl) analyses

Salt levels were determined by AOAC 24.010 (4) on day 0 and 15 of storage.

Nitrite analyses

Nitrite was analyzed using the AOAC 24.044 (4) sulfanilic acid method on day 0 and 15 of storage.

Thiobarbituric Acid analyses

The Tarladgis et al. (119) 2-thiobarbituric acid (TBA) as modified by Zipser and Watts (133) was used to determine TBA values on day 0, 6, 12, and 15 of storage.

Titratable acidity and pH

Ten grams of turkey were placed in a Waring blender with 100 ml of distilled water and homogenized for 1 minute. The pH of the slurry was taken using pH indicator strips (American Scientific Products, Stone Mountain, GA). The

sample was vacuum filtered through a Whatman number 4 filter paper. Using 0.1 ml phenolphthalein as an indicator, two 25 ml samples of the filtrate were titrated with 0.1 N NaOH. Both pH and titratable acidity were performed for each sampling day (0,1,3,6,9,12, and 15).

I. STATISTICAL ANALYSES

The data obtained from this experiment were analyzed using the Statistical Analysis System (SAS) (100) and Statgraphics software (118). Microbiological data were transformed into logarithms before analyses. Linear regression was used to evaluate the changes in microbial growth, titratable acidity and pH values caused by different formulations and different storage methods. The General Linear Model (GLM) procedure was used to perform the analysis of variance. GLM, with least square means and Duncan's New Multiple range test options, were performed to separate treatment means when found significant at $P<0.05$. Analysis of Variance was used to determine the main effects of salt, erythorbate, STPP, and their interaction on microbial data. All statistical analyses were based on a 95% confidence limit.

CHAPTER IV

RESULTS AND DISCUSSION

A. PROXIMATE ANALYSES

The fat content of turkey hams ranged from 11.41% to 18.49% for all treatments (Appendix 2). Protein content of turkey hams ranged from 18.40% to 21.26%. The average percent fat and protein for nine turkey hams was 14.08% and 19.35%, respectively. Fat and protein content did not differ significantly ($P>0.05$) among main treatment effects (Table 3). There were also no significant differences ($P>0.05$) among individual treatments (Appendix 2). All hams were formulated using the same amount of meat and the same amount of skin (fat). The differences between the 10% fat used for formulation and the percent shown by analysis can probably be attributed to cook loss. When juices are lost during cooking of a ham, fat in the product can become more concentrated.

Moisture analysis showed only one difference ($P>0.05$) among treatments (Table 3, Appendix 2). ANOVA table for moisture can be seen in Appendix 2 (Table A4). NaCl is supposed to increase water holding capacity of meat products by forcing proteins apart and allowing room for water (24,69,128). As NaCl levels increased, the increase in percent moisture was not observed. These results agree with

Table 3. Means of main treatment effects on percent protein, fat, moisture and ash in turkey hams formulated with selected levels of nonprotein food additives.

Treatment	Means			
	Protein	Fat	Moisture	Ash
NaCl levels				
1.5%	19.45 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
Phosphate				
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[c]				
0 ppm	19.51 a	14.77 a	67.76 a	2.34 a
550ppm	19.71 a	12.18 a	63.68 a	2.24 a
550ppm+0.5%STPP[d]	18.83 a	15.31 a	60.69 a	2.59 a

[ab] Column means within a treatment followed by different letters are significantly different ($P<0.05$).

[c] ppm = parts per million.

[d] STPP= sodium tripolyphosphate.

the literature (11,108). Phosphates have been shown to improve water binding in meat products and prevent cook loss (24,58,69,128). Treatments with added phosphate (Table 3) had a numerically lower mean moisture percent (60.69%) than the treatments with just NaCl (64.17%); however, only the STPP + 2.0% NaCl had a significantly lower ($P<0.05$) moisture content (Appendix 2). When main treatment effects were evaluated (Table 3), addition of phosphate had no significant effect ($P>0.05$) on moisture content. These results agree with several reports in the literature (11,108).

The percent ash of the 1.5% NaCl treatments was significantly less ($P<0.05$) than the percent ash of the 2.0% and 2.5% NaCl treatment (Table 3, Appendix 2), when main treatment effects were evaluated. As salt levels increased, the percent ash increased. Salt contains minerals, so as minerals were increased, percent ash increased. The addition of erythorbate and phosphate did not significantly ($P>0.05$) affect the percent ash in cooked turkey hams (Table 3). Increasing salt level by 0.5% increased the ash an average of 0.30%.

B. TBA ANALYSES

Least square means of TBA values for all treatment means represent TBA values as milligrams of malonaldehyde per kilogram of sample (Appendix 2). Initial TBA

values ranged from 0.133 to 1.106 in the first replication and 0.117 to 0.780 in the second replication. The initial mean TBA numbers were 0.548 and 0.337 for the first and second replications, respectively. Analysis of variance on main effects for TBA can be seen in Appendix 2. However, when main treatment means were evaluated, addition of erythorbate and phosphate significantly reduced ($P<0.05$) TBA values (Table 4). In both replications, no significant differences ($P>0.05$) were found in TBA values over salt levels, atmospheres or storage times (Table 4). Malonaldehyde levels decreased over time in some treatments and apparently was not a stable oxidation product in cooked turkey hams held at 4C. Other researchers have reported similiar changes (40). No significant differences ($P>0.05$) in TBA values were seen between aerobic and vacuum packaging. Hams from the first replication generally had higher TBA values (Appendix 2) than those of the second replication. Hams from the first replication were in frozen storage for a longer period of time than replication 2. Battkus (10) reported that frozen storage concentrated malonaldehyde, therefore causing higher TBA numbers. Lipid oxidation has been shown to increase progressively with sodium chloride concentration (84), a similiar trend was seen in our research (Table 4); however, these differences

Table 4. Means of treatment effects of NaCl, erythorbate, phosphate, atmosphere, and storage time on TBA values[a] in turkey hams held at 4C.

Treatment	Mean TBA values	
	Replication 1	Replication 2
NaCl levels		
1.5%	0.689 b	0.351 b
2.0%	0.809 b	0.341 b
2.5%	0.882 b	0.374 b
Erythorbate		
0 ppm	1.031 b	0.598 b
550 ppm	0.436 c	0.290 c
550ppm + 0.5% STPP[e]	0.905 b	0.177 d
Phosphate		
0	1.031 b	0.598 b
0.5%	0.905 b	0.177 c
Atmosphere		
aerobic	0.692 b	0.386 b
vacuum	0.889 b	0.324 b
Storage day		
0	0.548 b	0.337 b
6	0.791 b	0.399 b
12	0.893 b	0.342 b
18(15)	0.902 b	(0.342)b

[a] TBA values expressed as mg malonaldehyde per kilogram of sample.

[bcd] Means within a main treatment effect followed by different letters are significantly different ($P<0.05$).

[e] STPP = sodium tripolyphosphate.

were not significant at the 0.05 level. The addition of erythorbate significantly decreased ($P<0.05$) TBA values (Table 4). In the second replication, the addition of phosphate significantly reduced ($P<0.05$) TBA values. In the first replication, phosphate containing treatments also had a lower TBA value, but were not significantly different ($P>0.05$) from treatments containing no phosphate. Although the mechanism by which phosphate functions as an antioxidant is not completely understood, some researchers believe phosphate chelates free iron thus preventing the iron from oxidizing lipids. Phosphates also decrease oxidation by increasing the pH (22,84).

C. TITRATABLE ACIDITY AND pH

The initial pH values of turkey hams ranged from 6.1 to 6.6. The final pH values for aerobically packaged turkey hams held 15 days ranged from 6.0 to 7.7 while the vacuum packaged hams stored the same amount of time ranged from 5.7 to 6.6. Slopes of pH, representing changes in pH over storage, were significantly different ($P<0.05$) for vacuum packaged hams and aerobically packaged hams. In vacuum packaged products, lactobacilli, which produce lactic acid, predominate and can lower the pH of a product. Negative slopes for pH indicate prodiction of acid in the product over time (Appendix 2, Table A9). pH was not significantly affected ($P>0.05$) by any of the ingredients used in the

formulation. Although STPP improves functional qualities in meat products by increasing the pH (22,56,67,76), there was no significant increase ($P<0.05$) in the pH of hams in this study (Table 5).

Initial titratably acidity (TA) values ranged from 0.35% acid to 0.61% acid. The final TA values for aerobically packaged turkey hams was 0.21% acid to 0.71% acid with the vacuum packaged samples ranging from 0.23% acid to 0.73% acid. The slopes of TA values are shown in Appendix 2 (Table A9). There were no significant differences ($P>0.05$) between slopes of TA in vacuum and aerobic storage conditions (Table 5). The addition of phosphate and erythorbate had no significant effect ($P>0.05$) on the slopes of TA (Table 5). However, the slopes of TA , representing changes in TA over storage, were significantly decreased ($P<0.05$) as NaCl level increased. The 1.5% NaCl hams had a higher slope value which represents more acid production than the higher salt levels (Appendix 2, Table A9). Since higher salt levels, in meat, promote increased water binding; the hams with the higher salt levels may contain more water which could act to buffer acids.

Table 5. Mean slopes of main treatment effects on pH and titratable acidity (TA) in vacuum and aerobically packaged turkey hams held at 4C over the 0 to 15 day storage period.

	Mean	
Treatment	pH($\times 10^{-2}$)	TA($\times 10^{-2}$)
NaCl levels		
1.5	0.049 a	0.933 a
2.0	0.223 a	0.078 b
2.5	0.697 a	0.182 b
Phosphate		
0	-0.060 a	0.338 a
0.5%	1.072 a	0.506 a
Erythorbate[c]		
0 ppm	-0.060 a	0.338 a
550ppm	0.019 a	0.348 a
550ppm+0.5%STPP[d]	1.072 a	0.506 a
Atmosphere		
aerobic	1.570 a	0.237 a
vacuum	-0.976 b	0.558 a

[ab] Means within a main treatment effect followed by different letters are significantly different ($P<0.05$).

[c] ppm = parts per million.

[d] STPP = sodium tripolyphosphate.

D. NITRITE ANALYSES

Turkey hams were formulated using a target level of 156 ppm sodium nitrite. The average initial nitrite values after cooking for the treatments were 88 ppm for the salt (S) treatments, 72 ppm for the salt and erythorbate (S+E) treatments, and 43 ppm for the treatments formulated with salt, erythorbate and phosphate (S+E+P). Erythorbate can decrease the residual nitrite levels in meat by converting nitrite to nitrous acid. The addition of erythorbate showed no significant effect ($P>0.05$) on the amount of nitrite in the product (Table 6). The addition of phosphate significantly reduced ($P<0.05$) nitrite levels from 71 to 38 ppm (Table 6). The different salt levels showed no significant effect ($P<0.05$) on nitrite levels. Chemical oxidants can oxidize nitrite to nitrate (17,52) however, oxidation of nitrite did not occur in our study.

Nitrite levels decreased significantly ($P<0.05$) during the 15 day storage period. Results in Table 6 are in agreement with the research literature (82) that over time, nitrite levels decrease.

Table 6. Means of main treatment effects on nitrite in turkey hams held at 4C for 15 days.

Treatment	Mean nitrite[c] ppm
NaCl levels	
1.5%	62 a
2.0%	57 a
2.5%	54 a
Phosphate	
0	71 a
0.5%	38 b
Erythorbate	
0 ppm	71 a
550 ppm	64 a
550 ppm+0.5% STPP[d]	38 b
Atmosphere	
aerobic	54 a
vacuum	51 a
Storage	
0	68 a
15	53 b

[ab] Column means within a treatment followed by the same letter are not significantly different (P>0.05).

[c] nitrite concentration in ppm. ppm = parts per million.

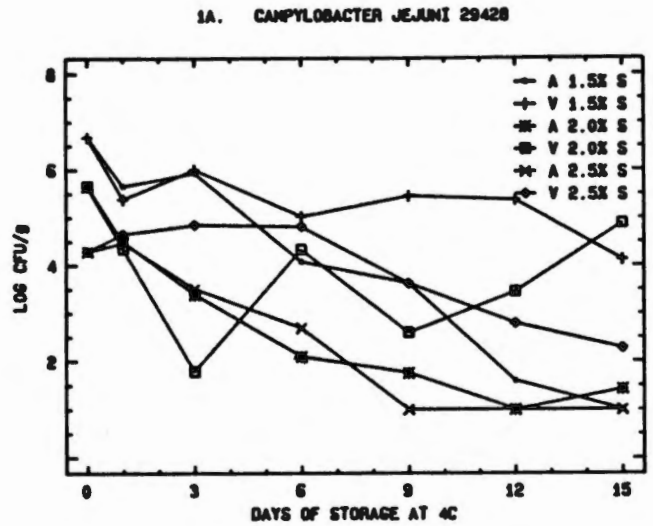
[d] STPP = sodium tripolyphosphate.

E. SURVIVAL OF CAMPYLOBACTER JEJUNI

Effect of NaCl on the survival of C. jejuni

Survival of C. jejuni in aerobic and vacuum packaged turkey hams formulated with selected levels of salt can be seen in Figure 1. Initial counts of Campylobacter strain ATCC 29428 ranged from approximately $\log_{10}$ 4.3 to 6.7 (Figure 1A). Turkey ham formulated with 2.5% salt had the lowest initial counts of C. jejuni 29428 ($\log_{10}$ 4.3) while the turkey ham formulated with 1.5% salt had the highest initial counts of C. jejuni 29428 ($\log_{10}$ 6.7).

Campylobacter 29428 was not detected after nine days of storage in the aerobically packaged ham containing 2.5% salt while the aerobically packaged ham formulated with 1.5% salt had survival of Campylobacter 29428 until day 15 of storage. Slopes representing changes in survival of C. jejuni over time at 4C are presented in Tables A10 and A11. All slope values representing survival of C. jejuni over time are negative since levels of C. jejuni decreased over storage. The ham containing 2.5% salt caused a significantly greater ($P<0.05$) decrease in the survival of C. jejuni 29428 than the ham containing 1.5% salt (Table 7). Survival of Campylobacter 29428 was greater in the vacuum packaged samples as opposed to the aerobically packaged samples (Table 7). Although this difference was not seen initially, as storage time progressed the greater survival under vacuum



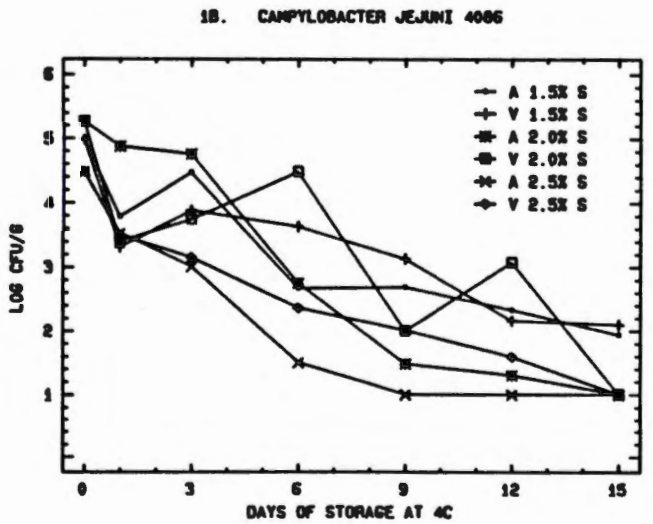


Figure 1. Survival curves of two strains of Campylobacter jejuni (ATCC 29428 and CJ-B4086) on aerobic (A) and vacuum (V) packaged turkey hams formulated with different levels of NaCl (S).

Table 7. Mean slopes of main effects on the survival of Campylobacter jejuni, and growth of aerobes, lactobacilli, and psychrotrophs in vacuum and aerobically packaged turkey ham stored at 4C for 0 to 15 days.

	Mean			
Treatment	CPC[f]	APC	LPC	PPC
NaCl levels				
1.5%	-0.277 a	0.141 a	0.137 a	0.158 a
2.0%	-0.390 ab	0.178 a	0.094 a	0.230 a
2.5%	-0.447 b	0.086 a	0.036 a	0.180 a
Phosphate				
0	-0.366 a	0.124 a	0.062 a	0.206 a
0.05%	-0.405 a	0.124 a	0.093 a	0.177 a
Erythorbate[d]				
0ppm	-0.366 a	0.124 a	0.062 a	0.206 a
550ppm	-0.322 a	0.157 a	0.111 a	0.185 a
550ppp+0.5%STPP[e]	-0.405 a	0.124 a	0.093 a	0.177 a
Atmosphere				
aerobic	-0.465 a	0.160 a	0.125 a	0.231 a
vacuum	-0.264 b	0.109 a	0.053 a	0.147 a

[ab] Column means within a treatment followed by different letters are significantly different ($P<0.05$).

[d] ppm = parts per million.

[e] STPP = sodium tripolyphosphate.

[f] CPC = campylobacter plate counts, LPC = lactobacilli plate counts, PPC = psychrotrophic plate counts.

became apparent (Figure 1A). The aerobically packaged hams had C. jejuni 29428 counts below detectable limits after 9 and 15 days in hams containing 2.5% and 1.5% salt, respectively. Aerobically packaged hams with 2.0% salt had C. jejuni counts of only log 1.4 CFU/g after 15 days. Vacuum packaged hams had C. jejuni counts of log 4.1, 4.9 and 2.3 CFU/g after 15 days for hams containing 1.5%, 2.0% and 2.5% salt, respectively. These data show that C. jejuni survived best under vacuum packaging. Being a microaerophilic organism, it is not surprising that C. jejuni survives best under conditions of low oxygen availability (93).

Campylobacter strain CJ-B4086 showed trends (Figure 1B) similar to that of Campylobacter 29428. Initial levels of C. jejuni 4086 ranged from approximately log 4.5 to log 5.3 CFU/g. The ham containing 2.5% salt had counts of C. jejuni 4086 below detectable levels at day 9 and 15 for aerobic and vacuum packaged samples, respectively. In aerobic and vacuum packaged hams with 2.0% salt the survival of C. jejuni 4086 fell below detectable levels after 15 days. Aerobic and vacuum packaged hams formulated with 1.5% salt had approximately log 2.0 C. jejuni/g after 15 days. Hams with the higher salt levels had significantly greater ($P<0.05$) detrimental effects on the survival of C. jejuni 40486 (Table 8). C. jejuni 4086 was inhibited more by

aerobic packaging of turkey hams at 2.5% salt levels as opposed to turkey hams 1.5% and 2.0% salt.

Effect of NaCl and erythorbate on survival of C. jejuni

Survival of C. jejuni 29428 under aerobic and vacuum packaging in turkey ham formulated with selected levels of NaCl and erythorbate can be seen in Figure 2A. Inhibitory effects of NaCl together with erythorbate on C. jejuni 29428 can be seen immediately after inoculation. C. jejuni 29428 had an initial level of approximately log 6.0 C. jejuni/g in the ham with the 1.5% salt concentration and erythorbate. The hams containing 2.0% and 2.5% salt and erythorbate had initial C. jejuni counts of log 4.1 and 4.2 CFU/g, respectively. The aerobically packaged hams formulated with 2.0% and 2.5% salt and erythorbate decreased C. jejuni 29428 survivability rapidly with counts below detectable levels after 6 days. Differences in Campylobacter survivability between aerobic and vacuum packaging were not apparent during initial days of storage at 4C. After 3 days, vacuum packaged ham with the 2.0% salt concentration and erythorbate had approximately log 3.7 C. jejuni/g while aerobically packaged ham containing 2.0% salt and erythorbate had approximately log 2.0 C. jejuni/g. The difference between aerobic and vacuum packaging was not as evident in the 1.5% salt and erythorbate ham; at day 1 the log CFU/g were higher for aerobically packaged ham but

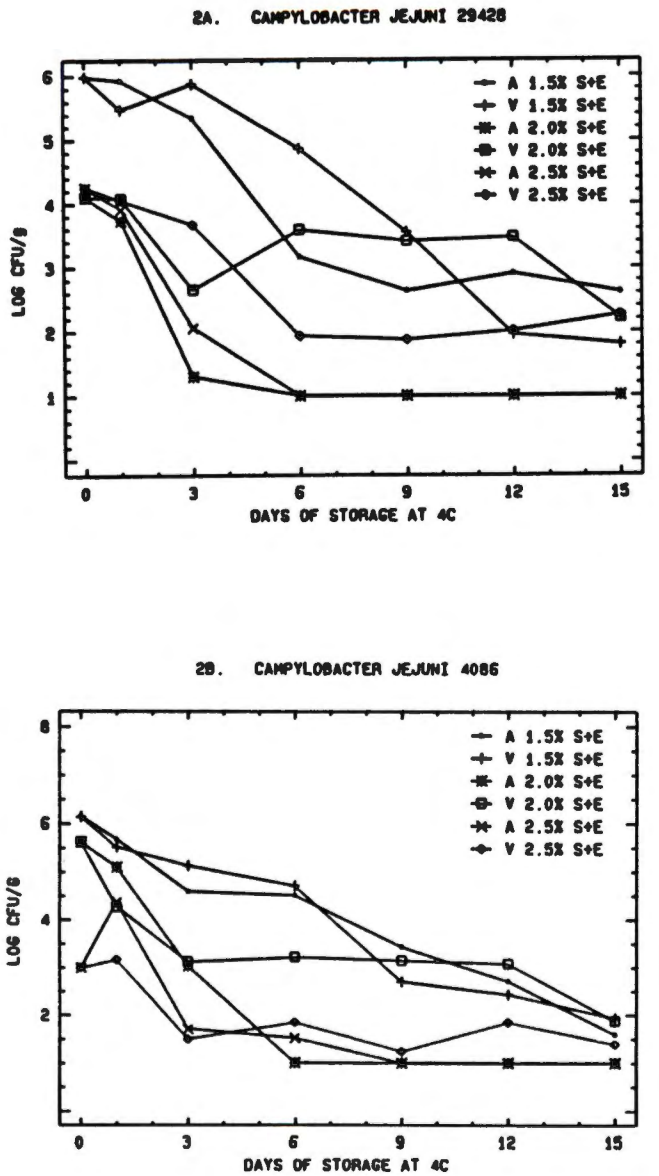


Figure 2. Survival curves of two strains of Campylobacter jejuni (ATCC 29428 and CJ-B4086) on aerobic (A) and vacuum (V) packaged turkey hams formulated with different levels of NaCl in combination with erythorbate (S+E).

after day 1 of storage at 4C the vacuum packaged ham had higher log $_{10}$ C. jejuni/g. After day 9, in the hams containing 1.5% salt and erythorbate, the aerobically packaged treatments had a higher log $_{10}$ CFU/g than the vacuum treatments.

Initial levels of C. jejuni 4086 ranged from approximately log $_{10}$ 3.0 to log $_{10}$ 6.1 CFU/g (Figure 2B). The toxic effects of NaCl in combination with erythorbate can be seen immediately after inoculation of C. jejuni 4086 into the turkey hams since hams formulated with 1.5% NaCl and erythorbate had approximately log $_{10}$ 6.1 CFU/g and hams formulated with either 2.0 and 2.5% NaCl in combination with erythorbate had approximately log $_{10}$ 5.6 and log $_{10}$ 3.0 CFU/g, respectively. C. jejuni 4086 decreased rapidly in all treatments at 4C over the 15 day storage period. C. jejuni 4086 decreased most rapidly in 2.0 and 2.5% NaCl plus erythorbate treatments held under either packaging method. Initial counts of log $_{10}$ 3.0 to log $_{10}$ 5.6 C. jejuni/g decreased to undetectable levels as early as 6 days of storage for aerobically packaged samples.

Initially vacuum packaging had no effect on C. jejuni 4086 since both vacuum and aerobically packaged turkey hams having 1.5% salt and 550 ppm erythorbate had approximately log $_{10}$ 6.0 C. jejuni/g. Similiarly, both aerobic and vacuum packaged hams containing 2.0% salt and erythorbate had log $_{10}$ 5.6 C. jejuni/g initially. Hams containing 2.5% NaCl

and erythorbate also had similiar counts in vacuum and aerobically packaged hams initially. The protective effect of vacuum packaging on survival of C. jejuni became noticable after six days in hams containing 2.0% NaCl and erythorbate since counts of C. jejuni 4086 in vacuum packaged hams were log 3.1/g; whereas, under aerobic packaging after six days, C. jejuni counts were below detectable levels (10 cells/g). Hams containing 2.5% NaCl and erythorbate were significantly ($P>0.05$) more inhibitory than lower salt to survival of C. jejuni. However, the addition of erythorbate to formulations did not significantly ($P>0.05$) change slopes of survival curves of C. jejuni (Table 7).

Effect of NaCl in combination with erythorbate and phosphate on survival of C. jejuni

Survival of C. jejuni in aerobic and vacuum packaged turkey hams formulated with NaCl, erythorbate and phosphate (S+E+P) can be seen in Figure 3. C. jejuni 29428 counts initially ranged from approximately log 4.0 to log 5.7. The immediate effect that NaCl had on the survival of C. jejuni 29428 can be seen in that the hams formulated with 2.5% S+E+P had the lowest C. jejuni counts while hams with 1.5% S+E+P had the highest C. jejuni counts. C. jejuni 29428 decreased rapidly in all aerobically packaged samples (Figure 3A). After 9 days, in the 1.5% and 2.5% S+E+P hams

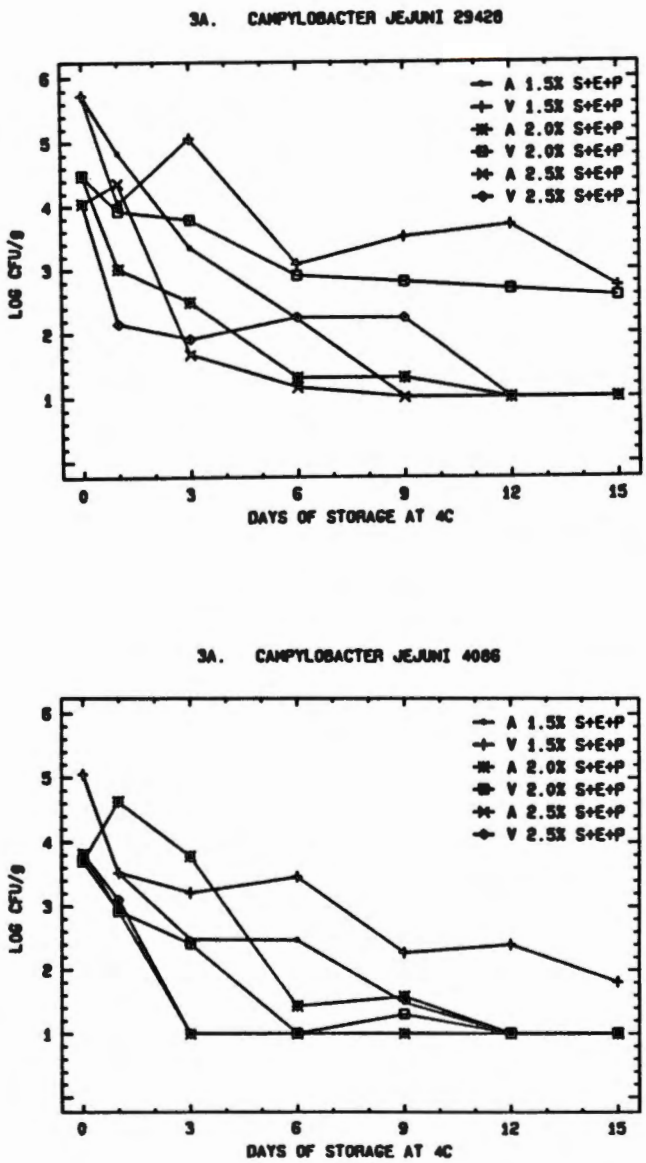


Figure 3. Survival curves of two strains of Campylobacter jejuni (ATCC 29428 and CJ-B4086) on aerobic (A) and vacuum (V) packaged turkey hams formulated with different levels of NaCl in combination with erythorbate and phosphate (S+E+P).

under aerobic conditions, C. jejuni 29428 could not be detected (<10 cells/g). At day 12, C. jejuni 29428 fell below detectable limits in the vacuum packaged 2.5% S+E+P ham and in the aerobic 2.0% S+E+P ham. After 15 days in vacuum packaged 1.5% and 2.0% S+E+P samples, C. jejuni counts were log 4.6 and 4.7, respectively. In all treatments, C. jejuni 29428 survived for longer periods in vacuum packaged samples than in aerobically packaged samples. In aerobically packaged samples, C. jejuni 29428 counts declined below detectable levels at days 9, 12 and 9 for 1.5%, 2.0% and 2.5% S+E+P, respectively. In vacuum packaged samples, C. jejuni 29428 counts fell below detectable levels on day 12 in the ham formulated with 2.5% S+E+P, while the vacuum packaged 1.5% and 2.0% S+E+P hams had C. jejuni 29428 counts of log 2.7 and 2.6 CFU/g, respectively.

Survival curves of C. jejuni 4086 in hams formulated with S+E+P can be seen in Figure 3B. Initial counts ranged from approximately log 3.7 for 2.0% and 2.5% S+E+P hams to log 5.0 for hams formulated with 1.5% S+E+P. Both aerobically and vacuum packaged hams containing 2.5% S+E+P showed no detectable C. jejuni counts at 3 days of storage. Both aerobically and vacuum packaged hams containing 2.0% S+E+P and the aerobically packaged 1.5% S+E+P ham showed no detectable C. jejuni counts after 12 days. Vacuum packaged ham containing 1.5% S+E+P had C. jejuni level of

log 1.8 in turkey ham even after 15 days of storage at 4C.
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Thus, the lowest salt level of turkey ham under vacuum was significantly ($P<0.05$) more protective to C. jejuni. However, the addition of STPP to formulations did not significantly ($P>0.05$) change survival slopes of C. jejuni over time.

F. GROWTH OF SPOILAGE BACTERIA

Effect of 1.5% NaCl on spoilage bacteria

Growth curves of aerobes, lactobacilli and psychrotrophs in aerobic and vacuum packaged turkey hams formulated with 1.5% NaCl can be seen in Figure 4. Initial bacterial counts ranged from approximately log 1.7 to 2.2 CFU/g. Final
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counts ranged from approximately log 2.2 to 9.2 CFU/g,
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however,the majority of spoilage bacteria counts were below log 5.4 CFU/g. Lag phase of lactics was extended
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throughout the storage period for vacuum packaged turkey hams stored at 4C. In vacuum packaged turkey hams, APC entered log growth after only 1 day; after 15 days the aerobic count was log 9.2 CFU/g. The vacuum packaged
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turkey hams with 1.5% NaCl supported the least lactobacilli growth with approximately log 2.2 CFU/g after 15 days of
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storage at 4C.

Slopes representing growth of aerobic, psychrotrophic and lactic spoilage microflora over storage are shown in Appendix 2, while main effects are shown in Table 7.

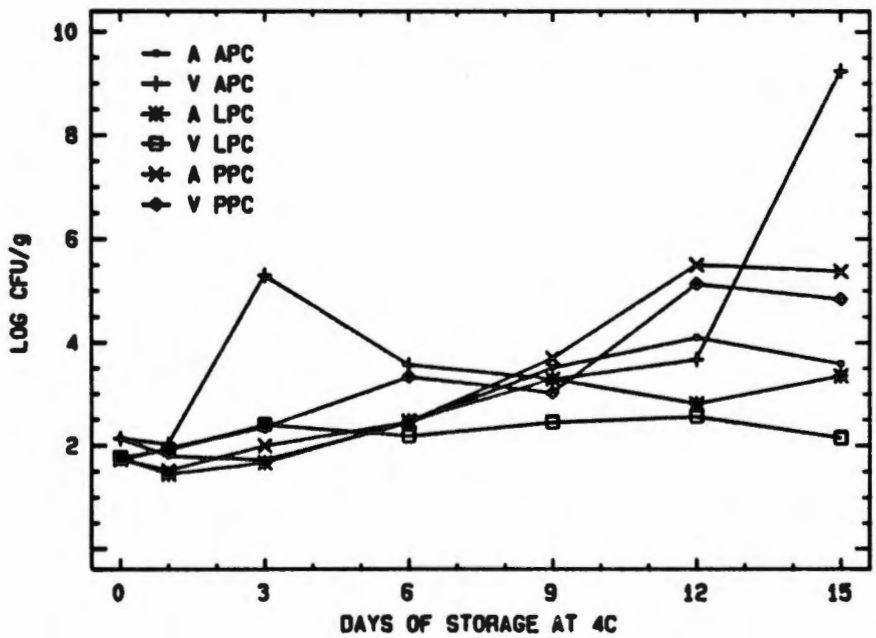


Figure 4. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 1.5% NaCl and stored for 15 days at 4C.

slopes of overall growth curves were not a good descriptor of each treatment since lag phase varied for each type of microorganism and treatment. Slopes were not significantly different ($P>0.05$) for each main treatment effect (Table 8) for any of the spoilage bacteria (APC, LPC, PPC). Work needs to be done to find a better statistical tool for monitoring growth rate changes by treatment over extended periods of time.

Effect of 2.0% NaCl on spoilage bacteria

Growth of aerobes, lactobacilli and psychrotrophs in aerobic and vacuum packaged turkey hams formulated with 2.0% NaCl can be seen in Figure 5. Initial spoilage bacterial counts ranged from approximately log$_{10}$ 2.1 to 2.8 CFU/g. Final counts ranged from approximately log$_{10}$ 3.1 to 5.8 CFU/g. The log phase of bacterial growth was delayed until after day 6 in most treatments. Lactobacilli, which had an initial count of log$_{10}$ 2.6 CFU/g and a final count of log$_{10}$ 3.1 CFU/g in vacuum packaged hams, were the slowest growing organisms with lag phase lasting until day 9. Aerobes in aerobically packaged turkey ham with 2.0% NaCl entered log growth after only 1 day. Psychrotrophs under both aerobic and vacuum packaging grew the quickest amoung spoilage bacteria. Aerobes, lactics, and psychrotrophs increased more redily in turkey hams containing 2.0% NaCl when aerobically packaged than when vacuum packaged.

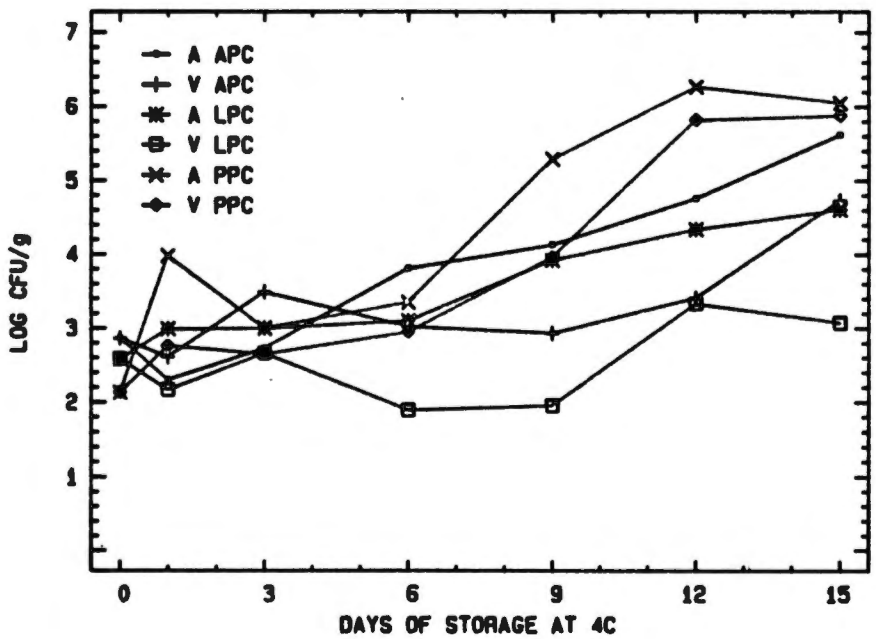


Figure 5. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 2.0% NaCl and stored for 15 days at 4C.

Effect of 2.5% NaCl on spoilage bacteria

Growth curves of aerobes, lactobacilli and psychrotrophs in aerobic and vacuum packaged turkey hams formulated with 2.5% NaCl can be seen in Figure 6. Initial bacterial counts ranged from below detectable levels to approximately log 1.5 CFU/g. Final bacterial counts were approximately log 1.3 to 3.0 CFU/g. After 15 days of storage at 4C, bacterial counts did not reach the log phase. Psychrotrophic bacteria grew quicker to higher log numbers than the other spoilage bacteria in both the aerobic and vacuum packaged turkey hams. LPC in vacuum packaged hams containing 2.5% NaCl had the least growth. Aerobic, lactic and pyschrotrophic bacteria grew more rapidly in turkey hams formulated with 2.5% NaCl when aerobically packaged than when vacuum packaged.

Effect of 1.5% NaCl in combination with erythorbate on spoilage bacteria

Growth curves of aerobes, lactobacilli and psychrotrophs in aerobic and vacuum packaged turkey hams formulated with 1.5% NaCl and erythorbate (S+E) can be seen in Figure 7. Initial bacterial counts ranged from approximately log 1.8 to 2.5 CFU/g. In most treatments log phase bacterial growth did not start until day 3 of storage at 4C. LPC in vacuum packaged hams containing 1.5% S+E had lag phase extended to day 9 of storage. Final bacterial

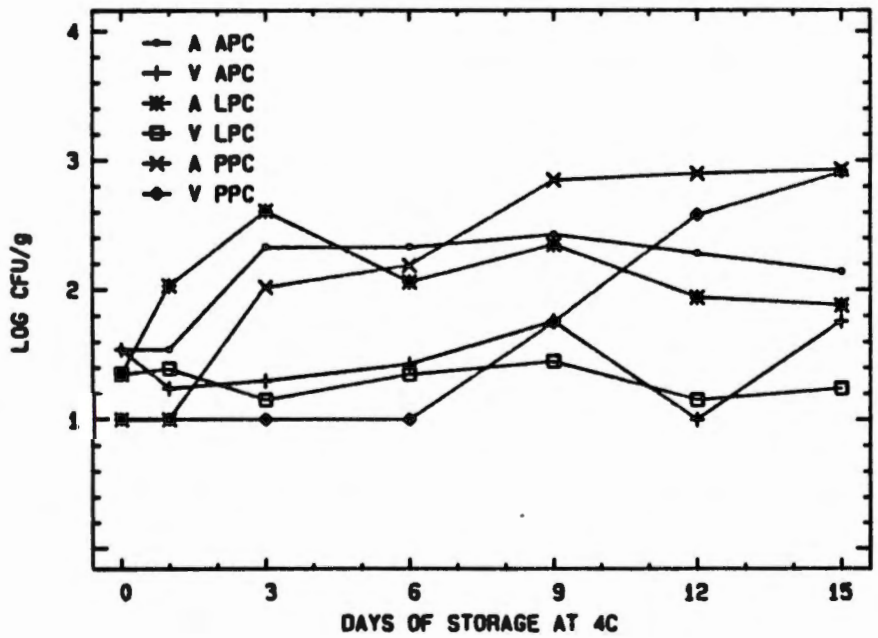


Figure 6. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 2.5% NaCl and stored for 15 days at 4C.

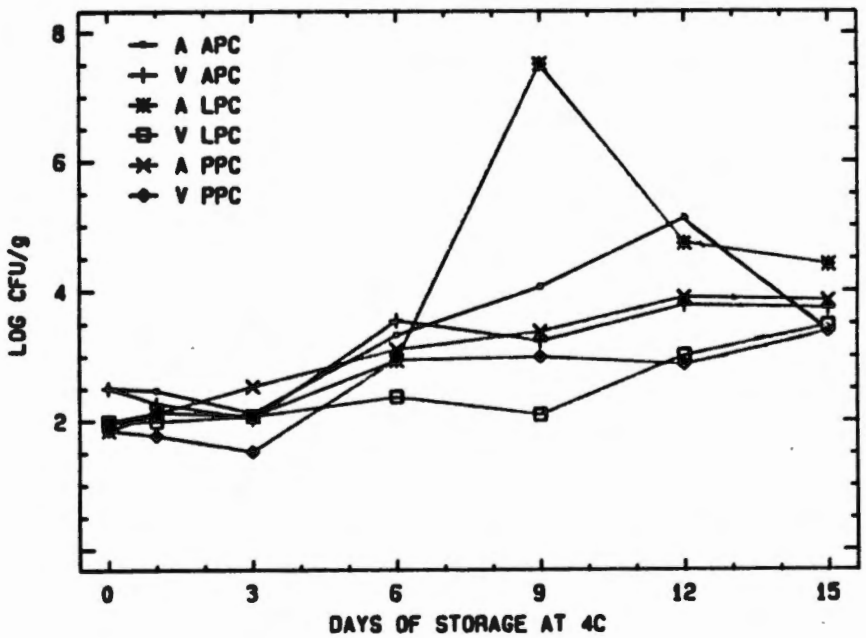


Figure 7. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 1.5% NaCl in combination with erythorbate and stored for 15 days.

counts ranged from approximately log$_{10}$ 3.3 to 4.7 CFU/g. Aerobic, lactic and psychrotrophic bacteria grew quicker to higher log numbers in turkey hams formulated with 1.5% S+E when aerobically packaged than when vacuum packaged. APC and LPC, when aerobically packaged, had the highest counts at 15 days of storage with approximately log$_{10}$ 4.7 and 4.4 CFU/g, respectively. Vacuum packaged hams had the lowest counts with approximately log$_{10}$ 3.5 and 3.3 CFU/g for LPC and PPC, respectively.

Effect of 2.0% NaCl in combination with erythorbate on spoilage bacteria

Growth curves of aerobes, lactobacilli, and psychrotrophs in aerobic and vacuum packaged turkey hams formulated with 2.0% S+E can be seen in Figure 7. Initial bacterial counts ranged from approximately log$_{10}$ 1.3 to 2.1 CFU/g. Aerobic bacteria had the highest initial counts of bacteria in aerobic and vacuum packaged turkey hams formulated with 2.0% S+E. Final counts ranged from approximately log$_{10}$ 2.5 to 7.3 CFU/g. The log phase began after 3 days of storage at 4C for APC in aerobically packaged hams and for LPC in both aerobic and vacuum packaged hams. The log phase was delayed until day 6 of storage for APC in vacuum packaging and for PPC in both aerobic and vacuum packaging. Aerobes, lactobacilli and psychrotrophs grew better in turkey hams with 2.0% S+E when the ham was aerobically packaged than when the ham was

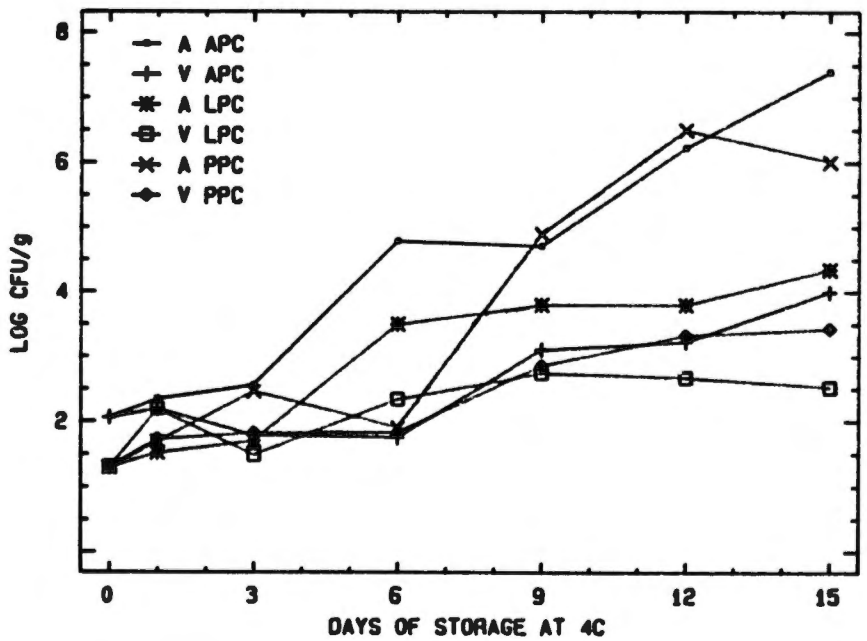


Figure 8. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 2.0% NaCl in combination with erythorbate and stored for 15 days at 4C.

vacuum packaged. APC and PPC in aerobically packaged hams had the highest final count with approximately log 7.3 and 6.0 CFU/g, respectively. The other four counts, LPC in aerobic packaged hams and APC, LPC and PPC in vacuum packaged hams, were all below log 4.4 CFU/g.

Effect of 2.5% NaCl in combination with erythorbate on spoilage bacteria

Growth curves of aerobes, lactobacilli and psychrotrophs in aerobic and vacuum packaged turkey hams formulated with 2.5% S+E can be seen in Figure 9. Initial counts ranged from below detectable limits to log 1.4 CFU/g with final counts ranging from approximately log 2.5 to 4.9 CFU/g. APC in both aerobic and vacuum packaging was below detectable limits initially. Log phase of psychrotrophs started after one day of storage at 4C when aerobically packaged. Log phase of lactics started after one days of storage at 4C and when vacuum packaged. Aerobes, lactics and psychrotrophs had higher counts on day 15 of storage in aerobically packaged turkey hams than when in turkey hams which were vacuum packaged. Psychrotrophic counts were the highest of all bacteria assayed in 2.5% S+E turkey hams when held under aerobic conditions.

Effect of 1.5% NaCl in combination with erythorbate and phosphate on growth of spoilage bacteria

Growth curves of aerobes, lactobacilli and psychrotrophs in aerobic and vacuum packaged turkey hams

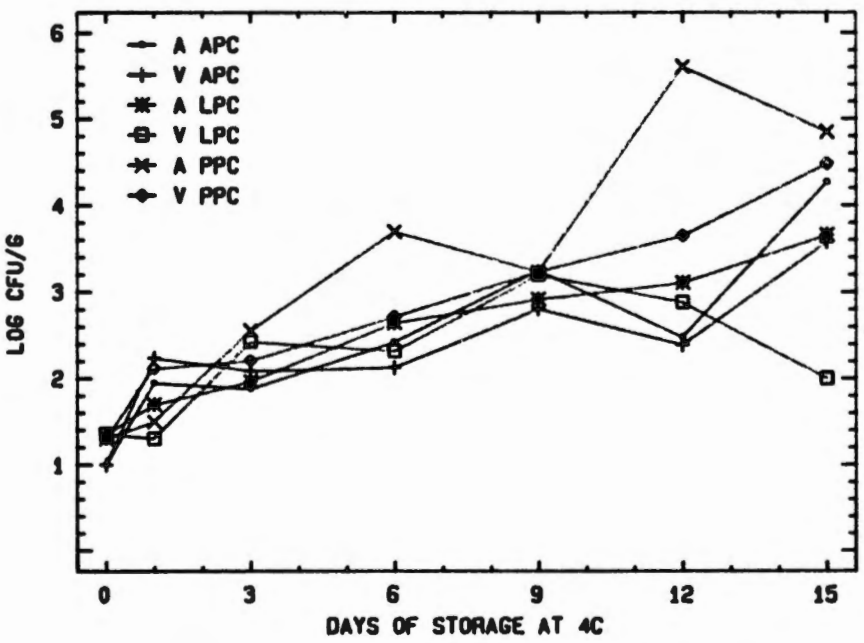


Figure 9. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 2.5% NaCl in combination with erythorbate and stored for 15 days at 4C.

formulated with 1.5% NaCl in combination with erythorbate and phosphate (S+E+P) can be seen in Figure 10. Initial counts ranged from below detectable limits to log 1.8 CFU/g with final counts ranging from log 1.4 to 8.0 CFU/g. Log phase growth started at day 1 of storage for psychrotrophs in aerobically packaged turkey hams and for aerobic bacteria in vacuum packaged turkey ham. Log phase growth started after day 6 of storage for lactics in aerobically packaged hams and after day 9 of storage for aerobes in aerobic packaging. Log phase was not evident, in LPC obtained from vacuum packaged hams, after 15 days of storage. Aerobic, lactic, and psychrotrophic bacteria grew more readily in turkey hams which were aerobically packaged than those which were vacuum packaged. Except for the LPC obtained from vacuum packaged turkey hams, all bacterial counts were fairly similiar until day 12 of storage when the bacteria in aerobically packaged turkey hams grew much more rapidly then the bacteria in vacuum packaged turkey hams.

Effect of 2.0% NaCl in combination with erythorbate and phosphate on the growth of spoilage bacteria

Growth curves of aerobic, lactic and psychrotrophic bacteria in aerobic and vacuum packaged turkey hams containing 2.0% S+E+P can be seen in Figure 11. Initial bacterial counts ranged from approximately log 1.8 to 2.9 CFU/g while final bacterial counts ranged from approximately

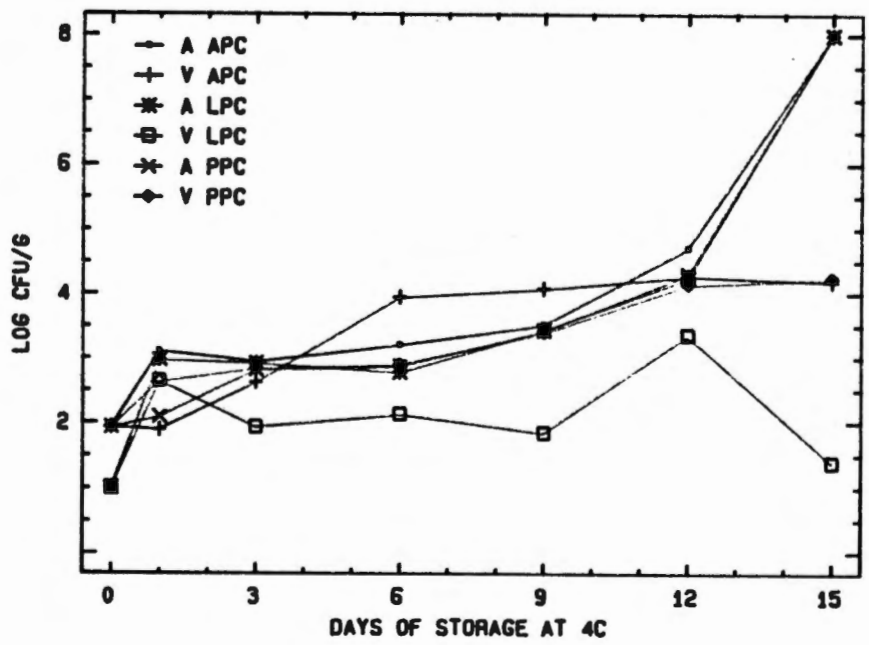


Figure 10. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 1.5% NaCl in combination with erythorbate and phosphate and stored for 15 days at 4C.

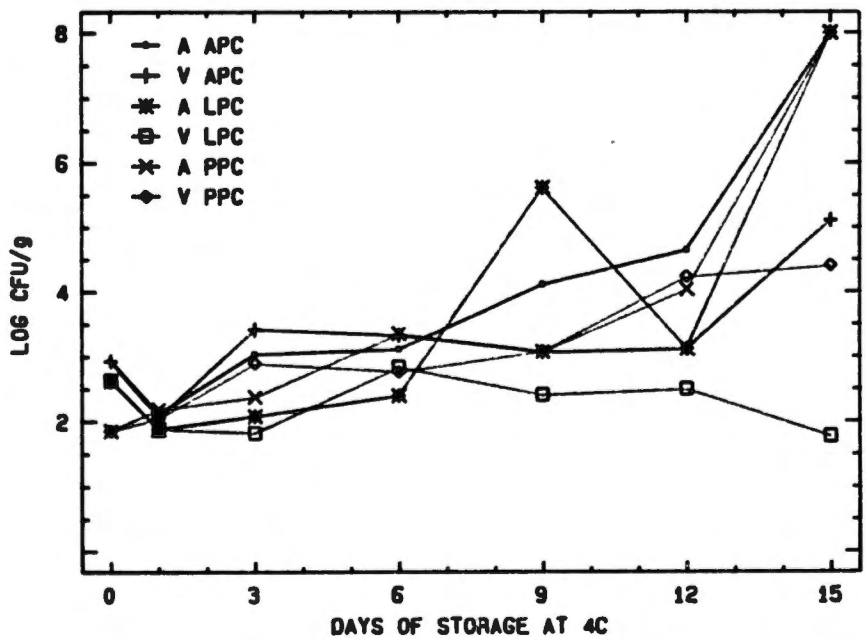


Figure 11. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 2.0% NaCl in combination with erythorbate and phosphate and stored for 15 days at 4C.

log 1.8 to 8.0 CFU/g. Aerobes, lactobacilli and
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psychrotrophs grew more quickly after 12 days of storage under aerobic packaging than when held under vacuum packaging; APC, LPC, and PPC were approximately log 8.0
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CFU/g. Log phase growth was not observed in LPC in vacuum packaged turkey hams. Lag phase was extended until day 9 for PPC in aerobic and vacuum packaged turkey hams and until day 12 for APC in vacuum packaged turkey hams.

Effect of 2.5% NaCl in combination with erythorbate and phosphate on the growth of spoilage bacteria

Growth curves of aerobic, lactic and psychrothrophic bacteria in aerobic and vacuum packaged turkey hams formulated with 2.5% S+E+P can be seen in Figure 12. Initial bacterial counts ranged from below detectable limits to approximately log 1.6 CFU/g. The LPC in vacuum packaged
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hams, which started as the highest initial count, fell below detectable limits (<10 cells/g) at day 12. The APC in vacuum packaged hams had no detectable colonies at day 15 of storage at 4C. Log phase growth was not apparent in LPC and APC in vacuum packaged turkey hams. PPC in both aerobic and vacuum packaged turkey hams had log growth after day 1. APC and LPC in aerobically packaged turkey hams increased at day 1 but growth slowed and lag phase was extended until day 12.

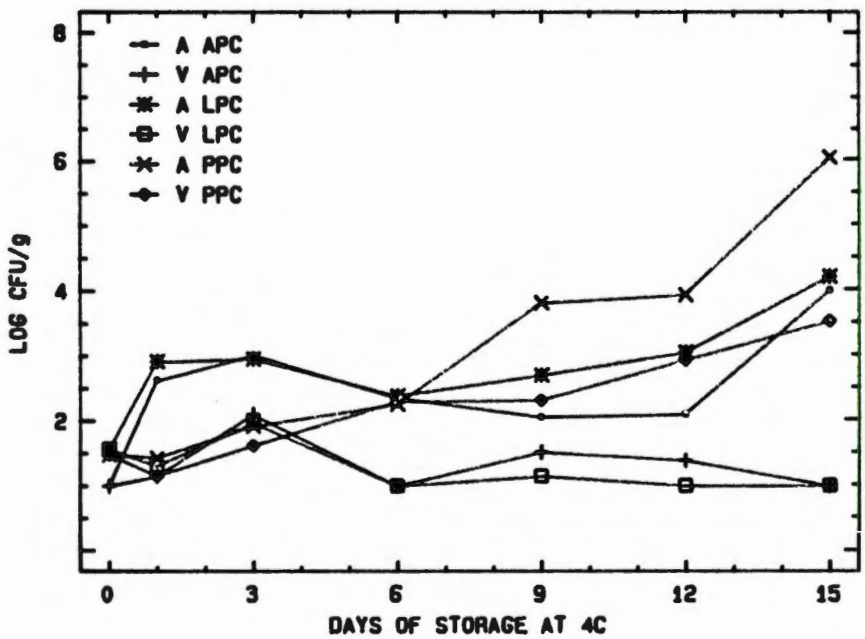


Figure 12. Growth curves of aerobes (APC), lactobacilli (LPC) and psychrotrophs (PPC) in aerobic (A) and vacuum (V) packaged turkey hams formulated with 2.5% NaCl in combination with erythorbate and phosphate and stored for 15 days at 4C.

Psychrotrophs in aerobically packaged turkey hams had the greatest growth with approximately log 6.1 CFU/g at 15 days of storage.

CHAPTER V

CONCLUSION

Vacuum packaging of turkey hams held at 4C significantly ($P<0.05$) improved survival of C. jejuni when compared to aerobic packaging. Vacuum packaging inhibited spoilage organisms, thus resulting in less competition for C. jejuni. The 2.0 and 2.5% salt levels under aerobic packaging caused the greatest decrease in survival of campylobacters. Addition of sodium erythorbate and sodium tripolyphosphate did not cause significant inhibition in the survival of Campylobacter. The addition of erythorbate to formulations reduced lipid oxidation of both vacuum and aerobically packaged turkey hams held at 4C as compared to salt or salt in combination with erythorbate and phosphate treatments. Although aerobic packaging of turkey hams and storage at 4C was optimal for inhibition of Campylobacter jejuni, turkey hams held under vacuum packaging at 4C with a level of either 2.0% or 2.5% NaCl in combination with 156 ppm nitrite, 550 ppm sodium erythorbate and 0.5% STPP can maintain a low level of spoilage bacteria while significantly ($P<0.05$) reducing survival of C. jejuni.

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LIST OF REFERENCES

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APPENDIXES

APPENDIX 1

INGREDIENT LIST FOR MODIFIED CARY-BLAIR TRANSPORT MEDIUM

Modified Cary-Blair Transport Medium

Sodium thioglycollate	1.5 g
Disodium phosphate	1.1 g
Sodium chloride	5.0 g
Agar	1.0 g
Distilled water	991.0 ml
Calcium chloride(1% solution)	9.0 ml

Autoclave 15 minutes at 121C.

APPENDIX 2

TABLES

Table A1. Percent protein, fat, moisture and ash in turkey hams formulated with selected levels of nonprotein food additives.

Treatment[a]	Salt level	Mean percentage			
		Protein	Fat	Moisture	Ash
S	1.5	19.92 b	12.40 b	68.31 b	1.97 bc
	2.0	18.94 b	15.82 b	62.78 bc	2.44 bc
	2.5	19.48 b	16.08 b	59.94 bc	2.61 bc
S+E	1.5	19.73 b	11.76 b	68.68 b	1.60 b
	2.0	18.92 b	13.36 b	66.96 b	2.41 bc
	2.5	18.60 b	11.41 b	67.63 b	2.71 bc
S+E+P	1.5	18.87 b	13.50 b	63.35 bc	2.21 bc
	2.0	21.26 b	18.49 b	54.30 c	2.66 bc
	2.5	18.40 b	13.94 b	64.43 b	2.91 c

[a]
S = salt
S+E = salt + erythorbate.
S+E+P= salt + erythorbate + phosphate.

bc
Means in the same column bearing the same letter are not significantly different (P>0.05).

Table A2. ANOVA table on main effects for protein composition in turkey hams.

Source	DF	SS	MS	F	PR > F
Salt level	2	1.277	0.634	0.78	0.4996
Error	6	4.906	0.818		
Formulations[a]	2	0.318	0.159	0.16	0.8535
Error	6	5.865	0.977		

[a] Formulations = salt, salt + erythorbate, salt + erythorbate + phosphate.

Table A3. 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	25.645	4.274		
Formulations[a]	2	16.821	8.411	1.95	0.2224
Error	6	25.863	4.310		

[a] Formulations = salt, salt + erythorbate, salt + erythorbate + phosphate.

Table A4. 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		
Formulations[a]	2	75.437	37.719	2.27	0.1843
Error	6	99.633	16.606		

[a] Formulations = salt, salt + erythorbate, salt + erythorbate + phosphate.

Table A5. 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	0.0086
Error	6	0.273	0.045		
Formulations[a]	2	0.199	0.100	0.53	0.6149
Error	6	1.131	0.188		

[a] Formulations = salt, salt + erythorbate, salt + erythorbate + phosphate.

Table A6. ANOVA table on main effects for TBA analyses on turkey hams.

Source[a]	DF	SS	MS	F	PR > F
Salt levels	2	7.073	2.358	20.53	0.0001
Error	121	13.895	0.115		
Formulations[b]	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	122	12.923	0.106		
Storage days	4	7.320	1.830	16.09	0.0001
Error	120	13.647	0.114		

[a] Source includes treatment + replication.

[b] Formulation = salt, salt + erythorbate, salt + erythorbate + phosphate.

Table A7. Least square means for TBA values[a] of vacuum and aerobically packaged turkey hams held at 4C for 0, 6,12 and 18 days (first replication).

Treatment[b]	Salt level	Vacuum 0	Vacuum 6	Vacuum 12	Vacuum 18	Aerobic 6	Aerobic 12	Aerobic 18
S	1.5	0.371	0.870	0.815	0.613	0.914	1.306	0.710
	2.0	0.856	1.147	1.549	1.034	0.838	1.495	1.880
	2.5	1.106	0.763	0.355	1.584	1.126	1.332	1.724
Means		0.778	0.927	0.906	1.077	0.959	1.378	1.438
S+E	1.5	0.133	0.154	0.144	0.137	0.355	0.688	0.773
	2.0	0.263	0.219	0.515	0.298	0.652	0.701	0.800
	2.5	0.290	0.446	0.415	0.491	0.771	0.837	0.695
Means		0.229	0.273	0.358	0.309	0.593	0.742	0.756
S+E+P	1.5	0.978	1.192	0.419	0.497	1.207	1.533	1.236
	2.0	0.311	0.572	0.701	1.790	0.744	0.940	NA
	2.5	0.624	1.128	1.204	1.119	1.145	1.131	0.864
Means		0.638	0.964	0.775	1.135	1.032	1.201	1.050
Overall means		0.548	0.721	0.680	0.840	0.861	1.107	1.081

[a] TBA vaulues expressed as mg malonaldehyde/kg sample.

[b] S = salt.
S+E = salt + erythorbate.
S+E+P= salt + erythorbate + phosphate.

NA Not available due to sample spoilage.

Table A8. Least square means for TBA values[a] of vacuum and aerobically packaged turkey hams held at 4C for 0, 6,12 and 15 days (second replication).

Treatment[b]	Salt level	Vacuum 0	Vacuum 6	Vacuum 12	Vacuum 15	Aerobic 6	Aerobic 12	Aerobic 15
S	1.5	0.780	0.390	0.468	0.390	0.858	0.468	0.468
	2.0	0.468	0.624	0.390	0.546	0.702	0.468	0.780
	2.5	0.585	0.702	0.624	0.624	0.546	0.780	0.858
Means		0.611	0.572	0.494	0.520	0.702	0.572	0.702
S+E	1.5	0.234	0.468	0.312	0.234	0.468	0.390	0.390
	2.0	0.156	0.390	0.312	0.156	0.312	0.312	0.156
	2.5	0.351	0.156	0.234	0.234	0.468	0.234	0.234
Means		0.247	0.338	0.286	0.208	0.416	0.312	0.260
S+E+P	1.5	0.117	0.078	0.156	0.156	0.156	0.156	0.156
	2.0	0.224	0.312	0.156	0.078	0.234	0.156	0.390
	2.5	0.117	0.156	0.234	0.078	0.156	0.312	0.234
Means		0.153	0.182	0.182	0.104	0.182	0.208	0.260
Overall means		0.337	0.364	0.321	0.277	0.433	0.354	0.407

[a] TBA values expressed as mg malonaldehyde/kg sample.

[b] S = salt.
S+E = salt + erythorbate.
S+E+P= salt + erythorbate + phosphate.

Table A9. Slopes for pH and titratable acidity (TA) in vacuum and aerobically packaged turkey hams held at 4C over the 15 day storage period.

Treatment	Salt level	TA(x10^{-2}) Vacuum	TA(x10^{-2}) Aerobic	pH(x10^{-2}) Vacuum	pH(x10^{-2}) Aerobic
S	1.5	0.72	0.82	-1.27	0.32
	2.0	0.25	-0.82	-1.79	-1.76
	2.5	0.25	0.81	+0.33	0.30
S+E	1.5	0.83	1.37	-1.18	2.07
	2.0	0.44	-0.08	-2.37	1.95
	2.5	0.05	-0.51	-0.85	-0.95
S+E+P	1.5	1.40	0.47	-0.75	1.10
	2.0	0.58	0.10	-0.16	3.56
	2.5	0.52	-0.02	-0.48	0.35

a S = salt.
S+E = salt + erythorbate.
S+E+P= salt + erythorbate + phosphate.

Table A10. Mean slopes representing survival of Campylobacter jejuni and growth of aerobes, lactobacilli, and psychrotrophs in aerobically packaged turkey ham stored at 4C for 0 to 15 days.

Treatment[a]	Salt level	Mean Slopes CPC	APC	LPC	PPC
S	1.5	-0.305 b	0.144 b	0.094 b	0.204 b
	2.0	-0.534 bc	0.251 b	0.180 b	0.350 b
	2.5	-0.482 bc	0.030 b	0.028 b	0.140 b
S+E	1.5	-0.278 b	0.173 b	0.202 b	0.139 b
	2.0	-0.319 bc	0.264 b	0.208 b	0.308 b
	2.5	-0.656 c	0.131 b	0.117 b	0.228 b
S+E+P	1.5	-0.411 bc	0.125 b	0.138 b	0.183 b
	2.0	-0.514 bc	0.177 b	0.074 b	0.239 b
	2.5	-0.681 c	0.134 b	0.082 b	0.289 b

[a] S = salt.
S+E = salt + erythorbate.
S+E+P= salt + erythorbate + phosphate.

[bc] Means in the same column bearing the same letter are not significantly different (P>0.05).

Table A11. Mean slopes representing survival of Campylobacter jejuni, and growth of aerobes, lactobacilli, and psychrotrophs in vacuum packaged turkey ham stored at 4C for 0 to 15 days.

Treatment	a Salt level	Mean Slopes CPC	APC	LPC	PPC
S	1.5	-.179 b	.162 b	.030 b	.189 b
	2.0	-.440 b	.126 b	.058 b	.230 b
	2.5	-.254 b	.029 b	-.016 b	.123 b
S+E	1.5	-.294 b	.098 b	.100 b	.123 b
	2.0	-.217 b	.125 b	.018 b	.117 b
	2.5	-.165 b	.138 b	.027 b	.192 b
S+E+P	1.5	-.191 b	.142 b	.042 b	.109 b
	2.0	-.190 b	.182 b	.027 b	.134 b
	2.5	-.442 b	.038 b	.014 b	.109 b

a
S = salt
S+E = salt + erythorbate.
S+E+P= salt + erythorbate + phosphate.

bc
Means in the same column bearing the same letter are not significantly different (P>0.05) .

VITA

Boyd Lee was born in Memphis Tennessee on February 17, 1963 to Boyd and Joan Lee. He graduated from Christian Brothers High School in Memphis in June 1981. That same year he entered the University of Tennessee, Knoxville and in June 1986 he received a Bachelor of Science degree in Agriculture. In September of 1986, he entered the graduate school at the University of Tennessee, Knoxville in the Department of Food Technology and Science and in December 1988 he graduated with a Masters of Science degree in that same field.

Boyd is a member of the Institute of Food Technologist. He is also a member of Gamma Sigma Delta an International Agricultural Honorary Society. During his graduate studies, he received the Rehabilitation Corporation of Tennessee Scholarship and the Stouffer Food Corporation Scholarship.