MICROBIOLOGICAL QUALITY OF HOT-BONED TURKEY BREAST MUSCLES

by

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INTRODUCTION

Demand for deboned poultry meat products has increased during the past ten years. Those further-processed poultry products, such as patties, nuggets, sandwiches, meat rolls and others, are fabricated from deboned-poultry meat, especially breast meat. The popularity of these foods has caused changes in poultry processing techniques. The term "hot-boning" or "hot-processing" is used to describe the technique of cutting carcasses soon after slaughter and before conventional chilling.

This new technique minimizes energy requirements. No extra energy is needed to cool the bones. Larger surface/volume makes heat transfer more efficient. Time, labor, and cost is saved (Nixon and Miller, 1967), and meat yield can be improved. Hot-boned muscles have higher pH, greater emulsifying capacity, and lower moisture and fat release upon heating when compared with chill-cut poultry meat (Lyon et al., 1983). The increase in exposed surface area of hot boned poultry meat increases potential for cross contamination or initial contamination due to handling, which is a major factor in shelf life and safety. Extensive research in this area has been done for red meat, but not for poultry meat.

Hot-boned meat is tougher when compared with the meat from conventionally processed poultry. Some treatments such as tumbling (Hamm, 1983), brining (Mathusa and Janky, 1984), and polyphosphate addition (Peterson, 1977) have been used to improve the tenderness. These treatments to improve tenderness might change the microbial quality of hot-boned poultry meat.

Many whole carcasses and further processed items are marketed frozen. About 80% of turkeys are marketed in the frozen form. Poultry can be kept in

good condition for months if freezing is prompt and rapid and the storage temperature is low enough. Since meat is not always used immediately after defrosting, it is necessary to define the effect of refrigerated storage on microbial quality, especially in comparison with fresh meat.

The purposes of this study were to determine (1) the microbial quality of hot-boned processed turkey breast muscles, (2) if tenderness improving treatments would effect the microbial quality on hot-boned turkey breast muscles, and (3) if frozen storage would effect the microbial quality on hot-boned turkey breast muscles.

LITERATURE REVIEW

I. Hot-Boning of Poultry Meat

In order to produce a cut-up bird rather than a whole bird at the poultry processing plant, traditional procedures for harvesting involve boning of fully processed, eviscerated and chilled carcasses. Birds are cut after chilling and aging for 6 to 24 hours until rigor mortis is past. In hot-boning, the muscles are stripped from carcasses immediately after evisceration while the body temperature is still warm. The term was first used in pork processing for cured ham by Mandigo and Henrickson (1966), and this technique improved meat palatability, yield and processing efficiency. It was then hypothesized that hot-boning could be used in poultry processing.

Nixon and Miller (1967) evaluated the one-hour postmortem hot boning technique on turkeys. They made rolls from hot-deboned turkey meat. The process eliminated evisceration, aging, bagging, freezing, and thawing of the whole carcass before fabrication. Labor requirement was significantly less. When evaluating the cost required, the total cost of cold boning procedure was 39.6 cents per bird, which was higher than the 18 cents per bird for hot boning procedure.

Hillcrest Poultry Inc. (Anonymous, 1970) reported that when using the conventional processing method, their birds picked up moisture and bacteria during chilling in ice and water. In order to solve the problem, a chill-pack system was used. The whole or split birds were removed from the eviscerating line and were cut warm, then they were packaged and stacked. Next, the meat was frozen in a -45°C tunnel for 90-110 minutes, depending on the outside temperature. After that, the carcasses were master-cartoned immediately,

palletized and stored at -2.2°C. These carcasses were found to pick up about 20% moisture when using this method. Texture, flavor, and color appeared to be improved.

Hamm (1981) tried to improve the hot boning method mentioned above. He developed a new unconventional poultry meat harvesting method. Breast and leg meat could be efficiently collected without eviscerating the bird, so considerable processing costs were saved. Defeathered, noneviscerated birds were used as the input material, thus eliminating the entire evisceration line with fewer operators on the line. Deskinned breast and leg meat, along with wings and liver, could be collected.

Lyon et al. (1983) deboned broiler dark meat 1 hour postmortem without chilling. Meat was ground through plates with 0.95- and 0.31-cm holes for sausage making. This hot deboned meat had significantly higher pH, emulsifying capacity, and released less moisture and fat than cold deboned meat. Sausage products were not significantly different in moisture and fat release. The products made from hot deboned meat showed significantly greater cooking loss and shrinkage, and were harder and chewier after cooking. This poor quality was because the sausage had been prepared in about 3 hours. The time period between deboning and incorporation into a product is critical to the subsequent product quality.

When evaluating nutrition changes caused by hot-boning technique, Zenoble et al. (1977) reported that percentages of protein, fat, and moisture were similar between hot-boned and commercially processed hens. Percentages of ash and thiamin were greater in hot-boned hens. Suderman and Cunningham (1980) found that skins from hot processed broilers had higher content of ash, moisture, magnesium, and sodium than skins chilled 24 hours in slush ice.

Calcium, potassium, and sulfur contents were not affected. Ang and Hamm (1983) reported that significantly higher moisture content was found in commercially processed breast meat of broilers but that significantly higher ash, phosphorus, and potassium levels were found in hot deboned breast meat. No differences were found for other nutrients.

Nixon and Miller (1967) reported that no real yield differences were apparent between hot and cold boning methods when they evaluated the hot-boning technique of turkey. But cooking loss of fabricated rolls did significantly favor the hot boning method. Wyche and Goodwin (1974) also reported that hot-cutting gave a higher cooking yield. Thigh parts had a higher cooking yield than breast parts. Treat (1971) reported that chill-cut birds had higher cut-up yield than hot-cut birds. Yet, during the storage period, hot-cut broilers lost less weight. However, Hale and Mayfield (1976) mentioned that hot-processed fowl meat had significantly higher yield. Hamm et al. (1982) compared the meat yield of hot noneviscerated processed and conventionally processed 7-week-old broilers. Hot-boned broilers had higher breast meat yields. However, total meat yields were greater from the conventionally processed broilers (Benoff et al., 1984). This was attributed to the differences in leg meat yield, which was primarily caused by absorption of water during immersion chilling.

Since the hot-boning technique interferes with muscle tenderization during the aging period, tougher meat results. The tough development depends on many factors, such as the length of time after slaughter and before cut is made, whether or not the muscle is in a pre-rigor state, the extent of cutting, and other factors. Generally, this effect is greater when the time period between slaughter and cutting is shorter.

In 1948, Lowe and Stewart noticed that if breast muscles of roaster or fowl were cut soon after slaughter, it would induce a turgidity and toughness. Klose et al. (1972) mentioned that the shear values showed a 30% increase in toughness on hot-cut broilers, which was statistically significant. Wyche and Goodwin (1974) found that chickens cut hot and not aged had higher shear values than the unaged chilled-cut parts. They also found that cut-up time did not significantly affect tenderness and no significant difference was found between birds hot- and chill-cut in their study. Stewart et al. (1984) reported that tenderness of meat was positively related to the higher pH values of meat. Hot-boning always caused an increased rate of postmortem pH decline and increased the toughness.

II. Microbial Consideration of Hot-Boned Poultry

One of the major considerations for hot-boned poultry is the microbiological quality and safety of meat. Increasing the surface area increases contamination opportunity. The elevated temperature of meat when handled also promotes microbial growth on both meat and equipment used for boning. Nottingham (1982) mentioned that if hot-boned meat was packed before cooling, the microbial flora would not be subjected to the cold-shock and dehydration normally affecting bacteria on the surface of conventionally chilled carcasses. Thus packaged hot-boned meat would appear to present a less hostile environment to microorganisms and undesirable bacteria might grow if it was not chilled rapidly. Considerable research has been done in red meat (Kastner et al., 1976; Fung et al., 1980; Fung et al., 1981), but less in poultry meat.

Hillcrest Poultry Inc. (Anonymous, 1970) found that warm birds, chilled

in ice and water, not only absorbed moisture but picked up bacteria from chill water. When a hot-cutting technique was used, bacterial counts on poultry at the end of the evisceration line were 50% to 60% less than counts on meat continuously chilled in ice and water.

Chen (1972) observed that a longer shelf life and a superior quality product were found for the hot packed chicken carcasses when he studied the effects of hot packing vs. ice-slush chilling. Psychrophilic counts for ice packed carcasses increased rapidly after a few days of lag phase, but this phase was longer for hot packed samples. Total Staphylococcus counts remained constant through the entire storage period for all treated samples.

Arafa and Chen (1977) found that cut-up hot-packaged broilers had a 5- to 7-day increase in shelf life when compared with broilers that had been immersion chilled. The shelf life of washed samples (after final wash and before entering an immersion chiller) was intermediate between hot-packaged and immersion chilled broilers. The lag phase of psychrotrophic bacteria was longer for the hot-packaged samples. During the entire storage period at 2-4°C, hot-packaged broilers maintained the lowest mesophilic counts. Lower coliform numbers and Staphylococcus-110 counts were found on immersion chilled broilers than on hot-packaged broilers. The predominant psychrotrophs on fresh immersion chilled broilers and on fresh hot-packaged broilers were Alcaligenes and Achromobacter, and Staphylococcus and Alcaligenes, respectively. The development pattern of spoilage-type microorganisms was the same for all treatments. Pseudomonas, and Enterobacter, were the two major genera isolated from spoiled broiler meat.

Microbiological characteristics of slush-ice chilled and hot-packaged broilers were investigated by Janky et al. (1978). Total aerobes and coliforms

were analyzed before and after chilling and hot-packaging. The results showed that both counts were higher on hot-packaged carcasses, which did not agree with the results of Arafa and Chen (1977). They also mentioned that after conventional oven-roasting of birds resulted in very low numbers of total aerobes. Neither coliforms nor fecal coliforms survived after cooking.

Lillard et al. (1984a) compared the levels and incidences of foodborne pathogens on breast meat, thigh meat, and skin removed from noneviscerated hot-boned broilers with or without spray washing to those from fully processed, chilled carcasses. The incidence of coagulase-positive staphylococci was not significantly different on meat and skin from both uneviscerated carcasses with and without a spray washing when compared to fully processed carcasses. The incidence of Clostridium perfringens was not significantly different among any of the sampling source, except that the incidence on fully processed breast muscle was lower than on breast muscles from uneviscerated carcasses without washing; and incidence on meat from fully processed thigh was significantly lower than on thigh from uneviscerated, spray-washed samples. Reduction of processing stages did not reduce the incidence of coagulase-positive staphylococci nor Clostridium perfringens, but did significantly reduce the incidence of Salmonella. Spray-washing for 2.5 minutes at 50 psi on hot-boned noneviscerated carcasses after defeathering did not significantly lower the incidence of Salmonella, coagulase-positive staphylococci, and Clostridium perfringens on either skin or meat, except that Salmonella was significantly decreased on thigh meat. Those results indicated that meat obtained from hot-boning noneviscerated carcasses was microbiologically as safe as meat obtained by boning fully processed, chilled carcasses.

Lillard et al. (1984b) also compared the total aerobic and Escherichia

coli counts between nonevisceratedd, hot-boned broiler carcasses and the fully processed chilled birds. Both skin and meat of breast and thigh were evaluated. Commercially boned parts of breasts and thighs meat had statistically higher counts than those from nonevisceratedd and hot-boned parts. No significant difference was found for skin between the two types of carcasses. Spray-washing (2.5 minutes at 50 psi) significantly decreased the total aerobic and E. coli counts. They concluded that the bacteriological quality of skin from nonevisceratedd carcasses was improved.

III. The Effect on Microbial Quality of Polyphosphates Treatment

Polyphosphates are widely used in meat processing. They contribute to flavor, water retention (Swift and Ellis, 1956; Mahon, 1962), color (Swift and Ellis, 1956), tenderness and juiciness (Spencer et al., 1962; Klose et al., 1963), decrease cooking shrinkage/loss (Mountney and Arganosa, 1963; Klose et al., 1963; Schermerhorn and Stadelman, 1963; Monk et al., 1964; Froning and Sackett, 1985), delay oxidative rancidity (Marion and Forsythe, 1962), and reduce thawing drip after frozen storage (Mahon et al., 1970) of poultry meat.

It is well known that polyphosphates are chelating or sequestering agents for metallic ions. Chain phosphates chelate metallic ions strongly, ring phosphates weakly, and orthophosphates not at all (Van Wazer and Callis, 1958). Because of this property, they have been reported to be bacterial growth inhibitors. They are also used in hot-boned poultry meat to reduce toughness (Peterson, 1977; Kardouche and Stadelman, 1978).

Mahon (1962) found that treating poultry with phosphates prior to normal processing and handling could improve quality and acceptance. A 6% phosphate solution was added to the chill water. This decreased the amount of water

absorbed per carcass, and increased the shelf life of refrigerated poultry.

Spencer and Smith (1962) chilled chicken fryer carcasses for 6 hours in ice water containing 10 oz of polyphosphate/gallon of water. The rate of microbial spoilage was found to be less when tested by plate count, uv fluorescence, and off-odor. Shelf life was increased by 1-2 days.

Elliott et al. (1964a) reported that both commercial polyphosphates and the equivalent mixtures of chemically pure polyphosphates inhibited the growth of nonfluorescent pseudomonads. The inhibition was caused by chelation of metal ions essential to the nonfluorescent pseudomonads. Natural competitive chelators such as pyoverdine and peptone reversed the inhibitory effect. The fluorescent pseudomonads was less sensitive to chelating power of polyphosphates than the nonfluorescent pseudomonads. Chilling chicken carcasses overnight in slush ice containing 3% or 8% polyphosphates lengthened subsequent shelf-life 17% and 25% respectively.

The use of 8% concentration of two commercial blends of polyphosphates in the chill water resulted in lower average bacterial counts on treated chicken carcasses (Steinhauer and Banwart, 1964). Statistical analysis for total and proteolytic count was not significantly different, however, lipolytic type microorganisms was found to be significantl lower. It was also mentioned that microbial contamination was almost entirely limited to coliform, lipolytic and proteolytic types and that polyphosphates did not alter the type of microorganisms on the carcasses.

Van Wazer (1971) reported that polyphosphates reduced the amount of gram positive bacteria and inhibited certain viruses in laboratory media. Bacteria such as Staphylococcus aureus, Salmonella typhimurium, Salmonella senftenberg, Pseudomonas fluorescens, Streptococcus faecalis, Achromobacter,

and Clostridium sporogenes were reported to be killed by polyphosphates. Kohl and Ellinger (1967) reported that gram negative bacteria seemed to be inhibited but not killed by polyphosphates.

The effect on Salmonella survival by adding a commercial brand of polyphosphates was studied by Foster and Mead (1976). Minced chicken breast and leg muscles held at 1°C, -2°C, -5°C, and -20°C were studied with or without addition of 0.35% polyphosphates. Without polyphosphates addition, survival of test organisms was greater in breast than in leg muscles. The highest survival occurred at -20°C in both types of muscles. Addition of polyphosphates increased the death rate of Salmonella in breast muscles held at -2°C and to a less extent at -20°C, but had little or no effect in leg muscles or in breast muscles held at 1°C or -5°C.

Mead and Adams (1979) reported that polyphosphate solutions (Puron) could be contaminated with microorganisms if not handled carefully. Injected carcasses showed a predominance of enterobacteriaceae and Aeromonas spp. In which case, injection of polyphosphate solution into chicken muscles would increase the number of microorganisms in the meat. However, the final counts after 14 days of storage at 1°C obtained from injected birds were not higher than those from non-injected controls even if polyphosphate solutions were contaminated, indicating an inhibitory effect of polyphosphates. The inhibitory effect on the muscle flora was less if chickens were stored at 10°C.

IV. The Effect on Microbial Quality of NaCl Treatment

Salt may be used to slow down or prevent the growth of microorganisms. A large amount of research, reviewed by Dukes and Janky (1984), showed that addition of sodium chloride increased tenderness of breast meat from

conventionally processed aged broiler carcasses. Salt will also decrease the toughness and increase the water holding capacity of hot-boned poultry meat (Furumoto and Stadelman, 1980; Mathusa and Janky, 1984).

The main factor responsible for inhibition of microbial growth by salt is the removal of available water. Low water activities, which limits the growth of microorganisms, may be brought about by the addition of sodium chloride. Part of the inhibitory effect is due to osmotic effect and the bacterial cell becomes plasmolyzed or dehydrated. A sodium chloride solution significantly decreased shear force values of light broiler meat (Nickerson and Sinskey, 1972).

Salting is more effective below 15.5°C, where the lower temperature reduces the growth rate of pathogenic and spoilage microorganisms, and provides for diffusion of salt into meat before significant growth can occur. Some species of lactobacteriaceae, Leuconostoc, Pediococcus, or Lactobacillus, which can grow well in presence of 3% sodium chloride and higher, are associated with the spoilage of cured cooked poultry meat. These microorganisms were reported to be inhibited by low temperature storage (Nickerson & Sinskey, 1972). None of them could grow at sodium chloride concentration above 5% when a temperature of 7.2°C or below was maintained. Usually 2%-5% salt in final products, together with refrigerated storage, or with the addition of acid and refrigerated storage, is sufficient to prevent the growth of psychrophilic and psychrotrophic microorganisms.

Kraft et al. (1963) found that freezing turkeys by brine immersion followed by air blast resulted in marked decrease in bacterial numbers on skin surfaces. Differences in total aerobes and coliforms on raw frozen birds and 5% NaCl brined birds were negligible when making smoked cornish game hens.

Janky et al. (1976) evaluated the effects of salt brine on microbiology of conventionally processed Cornish hens. Coliforms and total aerobes were counted after 5% NaCl brining. Both counts were highest immediately after thawing. Brining decreased both total aerobes and coliforms. After different cooking treatments, the unbrined meat had lower counts than the brined meat. The microorganisms in brine were also counted. Minimum total aerobes were found in freshly made salt brine. The number increased after 5 minutes from the time the birds were added, and then decreased after about 8 hours. Coliform counts immediately increased after birds were added in brine, but the number (4.6×10^1/ml) was still low enough to be insignificant.

Microbiological characteristics of 5% NaCl brine-chilled broilers were also evaluated (Janky et al., 1978). After sampling for 16 hours, there was approximately one log cycle reduction in numbers of aerobes and coliforms on the brine-chilled birds when compared with either hot-packaged or water-chilled birds. Conventional oven-roasting of birds resulted in very low numbers of aerobes present and neither coliform nor fecal coliform survived.

V. Effect of Frozen Storage on Microbial Quality

Newell et al. (1948) used semi-scalded, whole-eviscerated, and unpackaged chicken carcasses to compare the shelf life between birds frozen, thawed and held at 1.1°C and non-frozen birds. No statistically significant differences were found between the birds.

Spencer et al. (1961) reported the effect of freezing broilers on spoilage. Chicken broilers frozen at -45°C and -18°C for two-week intervals (2, 4, 6, 8, 10, and 12 weeks) and subsequently held in a thawed state at 1.1°C were studied. The number of days to spoilage after thawing for birds held

frozen in tray packages for each period studied was not significantly different from that of unfrozen control birds.

Wilkerson et al. (1961) reported that freezing inoculated turkeys at -30°C and storing at -2 to -10°C reduced coliforms more than enterococci. Two to three percent of enterococci persisted for 3-5 months, but no coliforms survived. Birds were equally contaminated with enterococci and coliforms when stored above freezing temperature. Yet, when testing the contamination of turkeys stored below freezing, only enterococci were important.

Kraft et al. (1963) compared the effect of brine immersion freezing and air freezing on survival of microorganisms on turkey skin. Both freezing methods resulted in marked decreases in bacterial numbers on skin surfaces. Air blast freezing was more effective if the initial bacterial loads were low. However, both methods destroyed 98% to 99% of total surface flora when initial total counts were high. The freezing method was more selective in eliminating viable cells when initial total counts were low.

Elliott and Straka (1964) reported that total counts of psychrophiles gave a better objective measurement of decomposition of chicken meat. Their studies showed that minced frozen-thawed chicken meat and frozen-thawed whole eviscerated chickens had shelf-lives at 2°C about equal to those of unfrozen chickens measured by psychrophilic counts and odor tests, regardless of length of frozen storage and thawing rate.

Quality of ground turkey meat after frozen storage was studied by Palmer et al. (1975). Ground turkey was prepared from fresh or from birds in frozen storage for 6 to 10 months. They were held at -12 to -19°C for 2, 4 and 8 months respectively. Tests showed that total aerobic bacterial counts varied slightly. Samples were then held in a refrigerator for 3 days under

simulated market condition. Meat from frozen turkeys supported more microbial growth than meat from fresh turkeys.

Microbiological quality of frozen fried chicken products was determined by Wang et al. (1976). The log number of mesophilic counts ranged from 2.90 CFU/g to 4.78 CFU/g, log psychrophilic counts ranged from 2.74 CFU/g to 4.66 CFU/g, and log Staphylococcus-110 medium counts ranged from 2.84 CFU/g to 4.54 CFU/g. Neither yeast nor mold was detectable and all chickens were Salmonella negative. Most of them were negative for coliforms, except a few were log 0.5 CFU/g to 0.8 CFU/g.

The microflora of fresh fryers was compared to that of defrosted frozen chicken (Sauter et al., 1978). The aerobic counts were similar as was the shelf life, which was 7.9 days for fresh and 8.1 days for thawed samples. Numbers of salt tolerant bacteria were similar on the first day, and remained constant at about this level on thawed frozen fryers until spoilage, but declined rapidly on fresh fryers.

Reddy et al. (1978) mentioned that freezing caused decreases in bacterial populations, but that spin chilling itself was highly effective in reducing counts. Three methods of freezing were used to study the microbiology of frozen commercially processed turkeys, shell freezing in a brine immersion tank at -19°C, air blast freezing at -29°C, and -21°C freezer. Freezing procedures did not significantly reduce mesophiles. The blast or holding freezer produced significantly lower counts of coliforms and psychrotrophs.

Smoked broiler carcasses were evaluated organoleptically and chemically by Koburger et al. (1981) after 1, 4, 6, 9, and 12 months of frozen storage at -18°C. Microbiological analysis indicated that quality can be maintained for at

least 12 months without serious changes. Only low levels of sporeformers and staphylococci were recovered on the total aerobic plates, no indicator organisms were detected.

MATERIALS AND METHODS

I. Sample Preparation

1. Turkey processing

Turkeys were obtained directly from a Norbrest turkey processing plant in Gibbon, Nebraska, and were processed in the plant. They were Nichols hens (5.87 Kg ave. wt.) and were 15-weeks of age. There were six groups of samples with different treatments (Table 1). Breast muscles were taken from every g)oup of carcasses for the experiment.

After slaughter, the first group of carcasses was conventionally chilled with slush ice and then the breasts were removed within 3 hours. The temperature of carcasses after chilling was recorded.

The second group of carcasses was hot-boned within 30 minutes after slaughter. The temperature of deboned carcasses was measured. The other four groups of samples were also hot-boned within 30 minutes, and different further treatments were then made. The breast muscles (ave. 0.5 to 0.8 Kg) were hand stripped by plant employees.

2. Further treatments on turkey breast muscles

Different treatments were made on the remaining groups of hot-boned turkey breast muscles. Treatments of the six groups are listed in Table 1.

The 50-gal barrel tumbler used in group 5 and 6 was obtained from Department of Food Science & Technology, University of Nebraska, Lincoln. It was first stored in a 2°C refrigerator overnight. Samples were tumbled (20 rpm) at 2°C.

Table 1. Treatments for turkey breast halves, either hot stripped or deboned after conventionally chilling.

GROUP	TREATMENT OF BREAST MUSCLES
Group 1	conventionally, slush-ice chilled on the carcass, deboned after chilling.
Group 2	hot-boned, then slush-ice chilled, no further treatments.
Group 3	hot-boned, then marinated 3 hours in slush-ice with 4% NaCl added.
Group 4	hot-boned, then marinated 3 hours in slush-ice containing Lem-O-Fos*.
Group 5	hot-boned, marinated in slush-ice, then tumbled for 1 hour.
Group 6	hot-boned, tumbled for 1 hour in bags containing solutions of Lem-O-Fos*.

* Lem-O-Fos = A mixture of sodium tripolyphosphate and lemon juice concentrate. A patented product of Stauffer Chemical Co., Westport, Conn.

Each group had 14 breast halves and every sample was packaged in aseptic Sample Plastic Bags. Following treatment, each group was returned to the laboratory at Call Hall, Kansas State University in iced containers.

3. Chilling tank water

The water in the plant chilling tanks was collected at noon after 4 hours operation. First and second tank chilling water was collected in sterile bottles. They were packed in ice for transport back to the laboratory for microbial analysis.

II. Microbial Procedures

1. The "0 time" enumeration

Microbial samples were taken on conventionally- and hot-cut turkey breast muscles immediately after they were deboned as the "0 time" testing. Twelve samples were taken randomly in each group using the swab method. Sterile cotton swabs, buffered rinse solutions (Jensen et al., 1978), and a sterile metal template were used to restrict swabbing to an area of 12.3 cm^2 on skin surfaces. Mesophile, psychrotroph, and 37°C total counts were made by plate count agar (DIFCO). Coliform count was made using violet red bile agar (DIFCO). Standard pour plate methods (Clark et al., 1978) were used.

2. Enumeration of microorganisms on breast muscles

Breast muscles from the 6 treatments were stored at 3.3°C. Mesophile, psychrotroph, 37°C total counts, and coliform counts were made. The media used and incubation time and temperature were as follows:

	MEDIA	INCUBATION TEMPERATURE	TIME
Mesophile	Plate Count Agar	32°C	48 hours
Psychrotroph	Plate Count Agar	7°C	10 days
37°C Total Count	Plate Count Agar	37°C	48 hours
Coliforms	Violet Red Bile Agar	32°C	24 hours

Standard pour plate methods were used. For violet red bile agar, all dark red colonies with an estimated diameter of 0.5 mm or more were counted. These counts were made every two days until they reached $10^8/cm^2$.

3. Enumeration of microorganisms in plant tank water

The number of microorganisms in the plant chill tank water was made after they were sent back to microbiological laboratory. After serial dilution, the water was tested for mesophiles, psychrotrophs, 37°C total counts, and coliforms. The media used and incubation time and temperature were the same as mentioned above.

III. Frozen Storage

Half of the collected breast samples were frozen and stored at -18°C as soon as they arrived at the laboratory. Each sample was packaged in a separate Sample Plastic Bag. After 5 months storage, they were thawed for microbial detection.

Before evaluating their microbial quality, the frozen samples were stored at 3.3°C overnight in order to defrost the meat. Mesophiles, psychrotrophs, 37°C total counts, and coliforms were determined by the same procedures

mentioned above.

IV. Statistical Procedures

All meat counts were reduced to counts per cm^2, and then were converted to logarithms (base 10). The difference in bacterial counts between conventionally processed and hot-boned turkey breast muscles was determined. The bacterial counts for hot-boned samples with further treatments were compared to controls, that is hot-boned without further treatment and conventionally processed samples. After frozen storage, the microbial differences among all groups were also tested. The difference for each group before and after frozen storage was tested. These tests were made by using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

I. The Microbiological Quality of Hot-Boned (HB) and Conventionally Processed (CP) Turkey Breast Muscles

1. The microbial comparison of HB and CP turkey breast muscles

Table 2 shows the microbial counts of HB and CP turkey breast muscles at the time of collection and during time of storage at 3.3°C. At 0-time, which was immediately after deboning, the HB group had significantly higher mesophiles, 37°C total aerobes, and coliforms. Psychrotrophic counts were similar for the two groups. During handling, HB carcasses had higher chance of contamination because of higher body temperature. The temperature of HB carcasses while sampling was 37.4°C, which was much higher than CP carcasses (4.4°C). CP samples were chilled in slush-ice for three hours. Keel and Parmeler (1968) reported that during processing operations, total aerobes on chicken carcass surfaces were significantly reduced by chilling in chill vats, and psychrophiles were removed mainly at low temperatures. Three hours of ice-slushing for CP turkey samples also decreased coliforms. Janky et al. (1978) also had the results of higher coliforms on HB broilers than on CP carcasses.

The first 24 hour period of refrigerated storage included the transportation time from plant to the laboratory. During transportation, samples were packed with slush-ice. The same effect of chilling carcasses in chill vats, was obtained, so microbial counts decreased. All counts decreased slightly but not significantly when compared with the 0-time evaluation, except that mesophiles and coliforms significantly decreased on HB samples. The low temperature of slush-ice packaging significantly decreased the coliforms on HB

TABLE 2. Microbial comparison of hot-boned and conventionally processed turkey breast muscles under storage at 3.3°C.*

DAY	Mesophile		Psychrotroph		37°C Total Aerobe		Coliform	
	CP**	HB	CP	HB	CP	HB	CP	HB
0	2.40^{a}	2.75	2.00^{de}	2.03^{df}	2.79^{l}	2.98^{m}	2.43^{p}	3.01
1	2.37^{ab}	2.45^{b}	1.93^{eg}	1.94^{fg}	2.74^{l}	2.93^{m}	2.37^{p}	2.76^{q}
3	3.85^{c}	4.01^{c}	3.20^{h}	3.04^{h}	3.66^{n}	3.64^{n}	2.31^{p}	2.67^{q}
6	5.94	5.32	4.42^{i}	4.38^{i}	4.68^{o}	4.58^{o}	2.42^{p}	2.68^{q}
9	7.29	6.00	5.91^{j}	5.78^{j}	6.06	5.52	2.38^{p}	2.61^{qr}
12	7.52	6.69	7.34	6.89	7.03	6.65	2.38^{p}	2.54^{r}
15	7.71	7.23	8.12^{k}	7.46	7.20	6.92	2.33^{p}	2.63^{qr}
18	7.98	7.52	8.20^{k}	7.93	7.55	7.32	2.26^{p}	2.60^{r}

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 7 samples except that 0-time value is the mean of 12 samples. Means with same letter superscripts within a microbial grouping are not significantly different at $p < 0.05$.

** CP = conventionally processed turkey breast muscles.

HB = hot-boned turkey breast muscles.

carcasses after 24 hours of storage. This condition was more apparent on HB samples than on CP samples because slush-ice chilling of CP carcasses before deboning had reduced the number of coliforms.

Microorganisms on HB carcasses appeared to have lower numbers than those on CP carcasses. After six days of storage HB breasts began to have significantly fewer mesophiles, and after nine days 37°C total aerobes were significantly fewer when compared with CP breasts. HB breasts tended to have less numbers on the surfaces although they had higher initial counts than the CP breasts. Actually, the 37°C total counts appeared to be similar between the two groups from the third day on. Psychrotrophic counts for the two groups of samples were also similar at first but then higher counts were found on CP samples during the entire storage period. CP samples always had significantly lower coliforms than HB samples. During the eighteen days of storage under 3.3°C, the counts did not change much for each group. Similar conditions were reported by Wilkerson et al. (1961) in that coliforms on refrigerated chickens tended to remain constant during storage for 15 to 20 days.

2. The microbial comparison of HB and CP turkey breast muscles after frozen storage

After five months of frozen storage at -18°C, the microbial counts on the surfaces of HB and CP turkey breast muscles are shown in Table 3. Lower numbers of microorganisms was still found on HB samples. Mesophilic counts of HB samples were lower than CP samples except that the counts for the first day after defrosting were similar. The same situation was also found for psychrotrophic and 37°C total counts. The difference between HB and CP

TABLE 3. Microbial comparison of hot-boned and conventionally processed turkey breast muscles after five months frozen storage.*

DAY	Mesophile		Psychrotroph		37°C Total Aerobe		Coliform	
	CP **	HB	CP	HB	CP	HB	CP	HB
1	2.14^{a}	2.11^{a}	2.59	2.39^{b}	2.77^{c}	2.59^{d}	1.54^{ef}	1.63^{eg}
3	2.80	2.47	2.93	2.56^{b}	2.92^{c}	2.65^{d}	1.57^{fh}	1.59^{ghi}
6	3.45	2.91	3.32	2.84	3.04	2.71	1.47^{fjk}	1.43^{ijl}
9	5.47	4.63	5.93	4.47	4.14	2.83	1.33^{km}	1.44^{ilm}
12	6.94	6.16	7.03	5.79	5.23	3.89	1.36^{kn}	1.38^{ln}
15	7.32	6.74	7.75	6.78	5.94	4.51	1.31^{ko}	1.40^{lo}
18	7.66	7.08	7.98	7.14	6.55	5.01	1.31^{kp}	1.39^{lp}

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 5 samples. Means with same letter superscripts within a microbial grouping are not significantly different at $p < 0.05$.

** CP = conventionally processed turkey breast muscles.

HB = hot-boned turkey breast musclese

samples at first was small, but became larger as refrigerated storage days increased. No significant differences were found for coliforms between the two groups of samples. Both counts decreased just very slightly during the storage period at 3.3°C after defrosting. HB turkey breast muscles appeared to have better microbial quality than CP breasts after freezing and thawing.

3. The microbial comparison of samples before and after freezing

When comparing microbial quality before and after freezing between HB and CP samples, a longer lag phase was noted for mesophiles, psychrotrophs, and 37°C total aerobes on surfaces of either HB or CP samples after being frozen then thawed. This was especially apparent for 37°C total aerobes. It was reported (Nickerson and Sinskey, 1972) that during the lag phase there was an increase in metabolic activity, enzyme systems were formed or repaired. The microorganisms needed more time to recover from frozen damage.

During 3.3°C of refrigerated storage, the amount of microorganisms on frozen-thawed samples were lower than on fresh samples for both HB and CP breast muscles. Less difference was found on CP samples when psychrotrophic counts were compared between frozen and unfrozen samples, although the difference was still significant. Elliott et al. (1964) stated that if the spoilage of chilled chicken meat was measured by plate counts at incubator temperature, which permitted the growth of mesophiles, it would cause a falsely longer lag phase and lower counts. This can also explain why 37°C total counts decreased more than mesophilic counts (32°C).

HB samples always had higher counts than CP samples during the first several days of storage but the differences were small or not significant. Lower counts were found on HB samples than on CP samples after several days

of refrigerated storage. After freezing, HB samples had lower counts during the entire 18 days of 3.3°C storage. Freezing caused the microbial counts of both HB and CP turkey breast muscles to be significantly different, it inhibited more microorganisms on HB samples.

II. Effect of Salt on the Microbial Quality of HB Turkey Breast Muscles

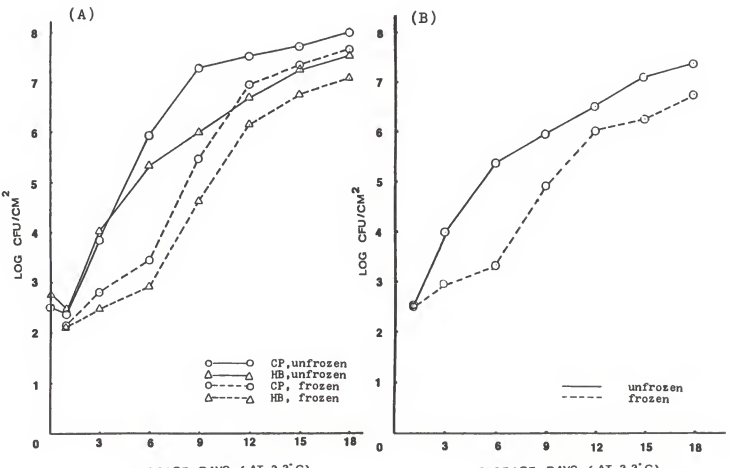
1. The microbial quality before freezing

Figures 1 to 4 compare the growth of mesophiles, psychrotrophs, 37°C total aerobes, and coliforms on turkey breast muscles for HB, CP, and group 3 samples. The mesophilic counts of group 3, which were hot-boned and then marinated in slush-ice with 4% NaCl added, were similar to the HB group during the first nine days, and were similar to the CP group during the first three days of storage at 3.3°C. Janky et al. (1978) reported that after 16 hours of soaking in a brine solution, chicken carcasses had a one log cycle reduction in numbers of aerobes and coliforms when compared to either hot-packaged or water-chilled birds. Since every carcass might have different microbial numbers depending on the level of contamination during processing, group 3 breasts had higher mesophilic counts than HB and CP breasts at first, although not significantly different. However, after nine days, group 3 breasts had significantly lower counts than HB samples.

In Figure 2, psychrotrophic counts on group 3 breasts were significantly higher than both HB and CP samples during the first day of storage, which was probably due to contamination. Yet, during the storage period, the numbers were similar for group 3, HB, and CP samples from the third day of storage, and were significantly lower for group 3 than for CP samples from the twelfth day of refrigerated storage. This was the same condition as the growth of mesophiles.

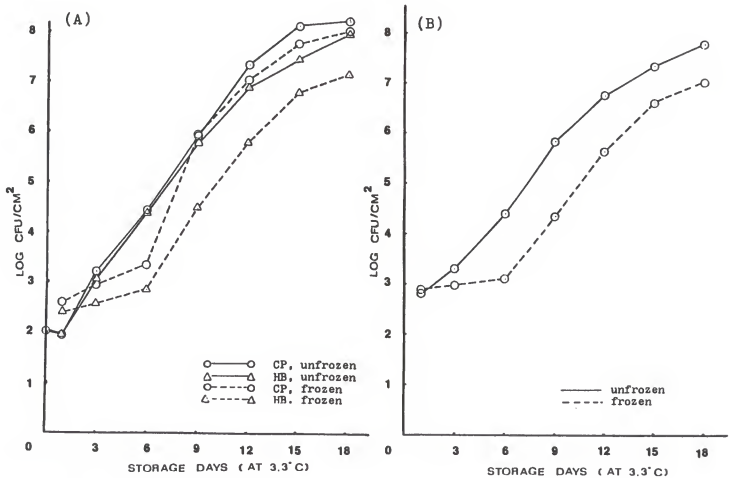
When the incubation temperature increased to 37°C, Figure 3 shows the counts for group 3 compared to HB and CP samples. All groups had similar counts on the first day. However, from the third day of refrigerated storage, significantly lower counts were found for group 3 than for either HB or CP

Figure 1. Comparison of mesophiles on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 3.



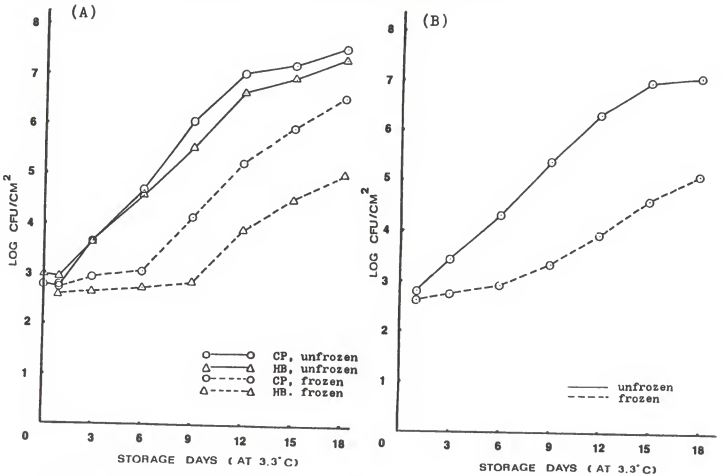
* The different treatments are described in Table 1.

Figure 2. Comparison of psychrotrophs on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 3.



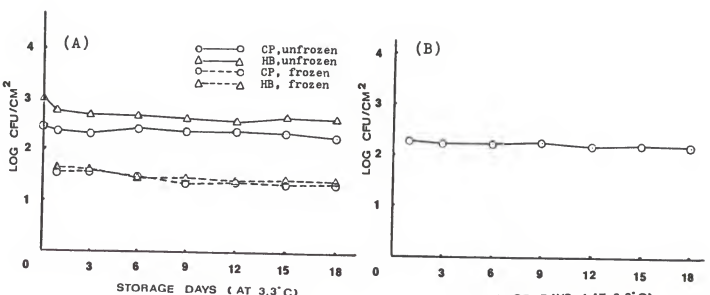
* The different treatments are described in Table 1.

Figure 3. Comparison of 37°C total aerobes on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 3.



* The different treatments are described in Table 1.

Figure 4. Comparison of coliforms on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 3.



* The different treatments are described in Table 1.

groups.

During the entire refrigerated storage of breasts in group 3, coliform counts remained almost constant. The same condition was found for HB and CP breasts as discussed earlier. Group 3 had significantly lower counts than both HB and CP groups, which agrees with Janky's (1978) report mentioned above.

Generally, salt marinating caused a slower growth rate for mesophiles and psychrotrophs during the entire refrigerated storage period. Although the difference was not significant at first when compared with the untreated breast muscles, salt marinated HB samples had significantly lower counts than the other two groups of samples and a longer shelf life.

2. The microbial quality after freezing

After salt marinated HB turkey breast muscles were frozen for five months, the numbers of both mesophiles and psychrotrophs on thawed samples surfaces right after defrosting, as recorded in Figure 1B and 2B appear to be similar to the microbial numbers on those samples before freezing. Both kinds of organisms were significantly less than the unfrozen samples at similar refrigerated storage times. Both mesophilic and psychrotrophic counts on the frozen-thawed group 3 samples were found to be significantly higher than group 1 and 2 frozen-thawed samples at the first day. Their differences were getting lower. After several days of storage, group 3 frozen-thawed samples began to have lower counts. Similar conditions were also found for unfrozen breasts, salt marination would not contaminate the breast muscles and the microbial quality of breast samples in group 3 could be improved or similar to the HB samples.

Figure 3B shows that the 37°C total counts on frozen-thawed breasts were significantly lower than for the unfrozen samples from the first day after

defrosting to the eighteenth day of storage. When comparing Figure 3A and 3B, salt marinated HB breasts had higher counts than HB samples, although the difference was not significant from the twelfth day.

Longer lag phases were noted for mesophiles, psychrotrophs, and 37°C total aerobes on surfaces of frozen-thawed group 3 breasts. These conditions were similar to those frozen-thawed HB and CP muscles, because the microorganisms needed more time to recover from freezing damage.

Numbers of coliforms on turkey breasts were found to decrease about 1.5 log cycles after freezing (Figure 4B). They were almost constant at the first six storage days and then became very small amount from the ninth day but still detectable (the amounts of coliforms decreased to very small in group 3, and the data can be seen in Table H). They were still significantly lower than both HB and CP samples after freezing storage. Defrosting did not cause further contamination of meat.

III. Effect of Polyphosphates on the Microbial Quality of HB Turkey Breast Muscles

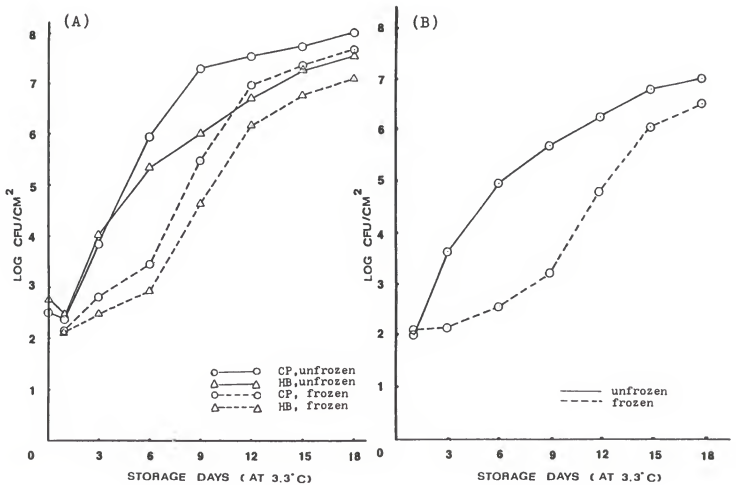
1. The microbial quality before freezing

Figure 5 shows the comparison of mesophiles on turkey muscle surfaces for HB, CP, and breasts in group 4. After the first day of refrigerated storage, samples marinated in slush ice with Lem-O-Fos for three hours had significantly fewer mesophiles than the HB samples, but were similar to the CP samples. The mesophilic counts for HB and CP breast muscles were similar after the end of the first day. Polyphosphate marinated HB samples had significantly lower counts on surfaces than CP samples after three days. The differences between polyphosphate treated and untreated HB samples were consistant during the entire storage period.

Psychrotrophs on this group of samples is shown in Figure 6. They appeared to be similar to both HB and CP samples at first. The counts were lower than either HB or CP breasts after three days, and the differences became greater with storage time. Polyphosphates did decrease the microorganisms on the surface of turkey muscles. This effect was more apparent for psychrotrophs than for mesophiles. That can be explained by the study of Elliott et al. (1964a). They mentioned polyphosphates significantly inhibited the growth of nonfluorescent pseudomonads, which was the main caused of poultry spoilage during refrigerated storage. Katzenlson and White (1950) reported that Na^+, K^+, Mg^{++}, S, P, and Cl^- or Br^- were necessary for growth of pseudomonads. Polyphosphates chelated the ions and inhibited the growth.

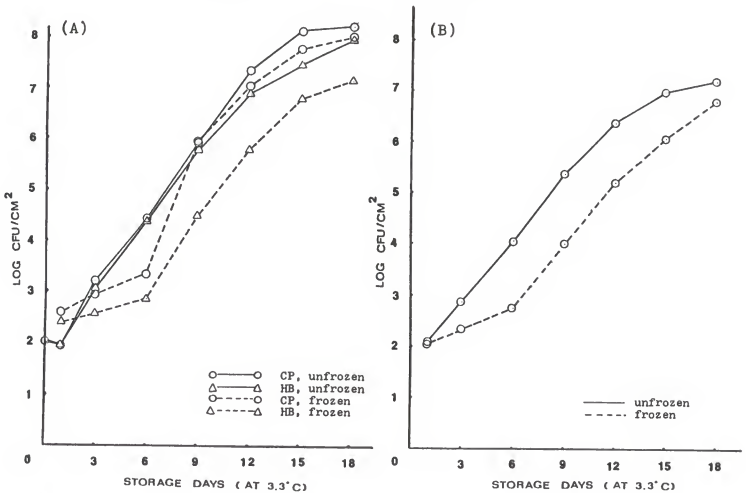
The 37°C total counts as shown in Figure 7 was similar to mesophilic counts for this group. Counts were significantly less than that for the CP

Figure 5. Comparison of mesophiles on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 4.



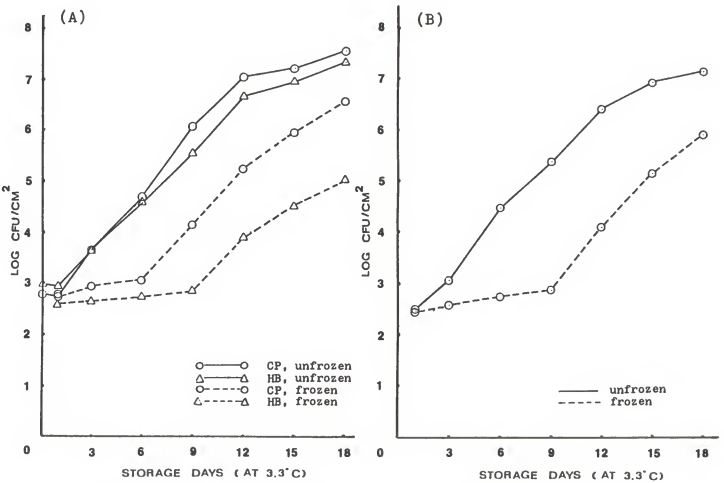
* The different treatments are described in Table 1.

Figure 6. Comparison of psychrotrophs on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 4.



* The different treatments are described in Table 1.

Figure 7. Comparison of 37°C total aerobes on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 4.



* The different treatments are described in Table 1.

group during the entire storage. The counts on HB samples were significantly higher than on polyphosphate treated HB samples during the first several days (Table C). Yet, this difference became insignificant as storage days increased. It was reported by Steinhauer and Banwart (1964) that total counts between polyphosphate treated and untreated chicken carcasses were not statistically different.

Coliform count remained steady during the entire refrigerated storage period, which can be seen in Figure 8. The counts for group 4 were not different from those of CP samples, but were lower than counts on HB samples. Since the treatment of group 4 was to marinate the HB turkey breast muscles in slush ice with polyphosphate for 3 hours, both polyphosphate and low temperature marination may have decreased the coliforms on the breast surfaces.

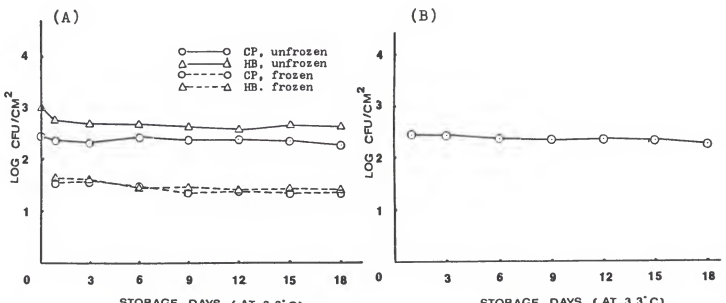
In group 4, polyphosphate mainly decreased the psychrotrophs on the meat surfaces. Total counts were not different from HB untreated samples. The effect of polyphosphate alone on coliforms could not be determined in these studies since the low temperature marination probably caused lower counts.

2. The microbial quality after freezing

Five months of frozen storage did not affect the microbial counts very much right after defrosting except for coliforms. Figure 5B, 6B, 7B and 8B show the microbial comparisons before and after freezing. The lag phases of the mesophiles, psychrotrophs, and especially 37°C total counts were longer than those on unfrozen samples. This caused the microbial counts to be significantly lower during the rest of the storage period.

Freezing decreased the coliform counts to very low amount. During

Figure 8. Comparison of coliforms on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 4.



* The different treatments are described in Table 1.

refrigerated storage after defrosting, sometimes they could not be detected. Table H gives these results. Wilkerson et al. (1961) mentioned that no coliforms survived on turkey meat after 3-5 months of frozen storage. Both polyphosphates and frozen storage decreased the original coliforms on unfrozen carcasses to very low counts.

Polyphosphate marinated HB samples had lower mesophilic and psychrotrophic counts than either CP or HB samples. However, the 37°C total counts on group 4 were higher than HB samples after the twelfth day of refrigerated storage. The microbial inhibition of polyphosphate marination was less effective on frozen-thawed breast muscles. Freezing gave more effect of microbial inhibition.

IV. Effect of Tumbling on the Microbial Quality of HB Turkey Breast Muscles

1. The microbial quality before freezing

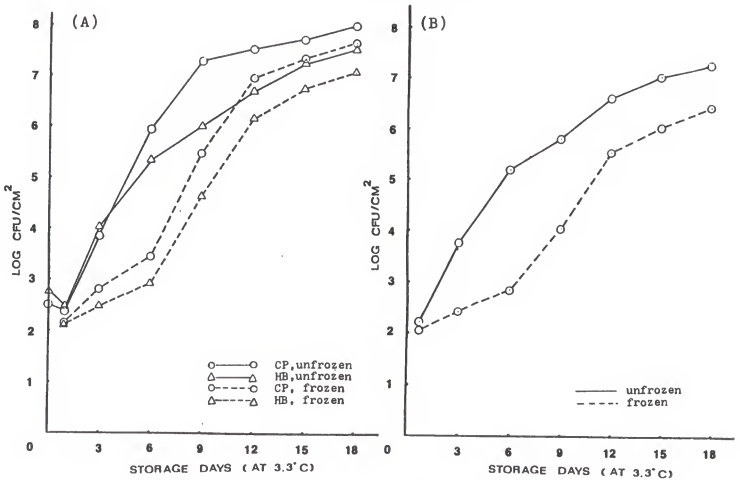
Figure 9 shows mesophilic counts on breasts in groups 1, 2, and 5. The tumbled HB samples had significantly lower mesophiles on the surfaces than HB untumbled samples after several days of storage. The difference became less as storage days increased. After 9 days, HB breasts with or without tumbling had similar counts. During the storage period, mesophiles on groups 2 and 5 were always less than those on CP samples.

Psychrotrophs (Figure 10) on tumbled HB samples (group 5) numbered about the same condition. In Figure 11, 37°C total aerobes were found to be the same initially, but later were less on group 5 breasts than on HB and CP samples, during the entire period. Greater differences were noted for 37°C total counts than for mesophiles and psychrotrophs.

From the results mentioned above, tumbling decreased the number of microorganisms on the surface of breasts. The growth curves of psychrotrophs, and 37°C total aerobes appeared to have 3 to 6 days of lag phases, which were not so apparent on the other groups. Few studies exist on the microbial quality of tumbled meat. However, Kotula et al. (1962) mentioned that use of a counterflow, tumbler type, high agitation continuous chiller significantly reduced total bacterial counts on chicken fryers when compared to chilling by air or agitated chilled water and that the degree of agitation was a factor affecting the change in bacterial counts.

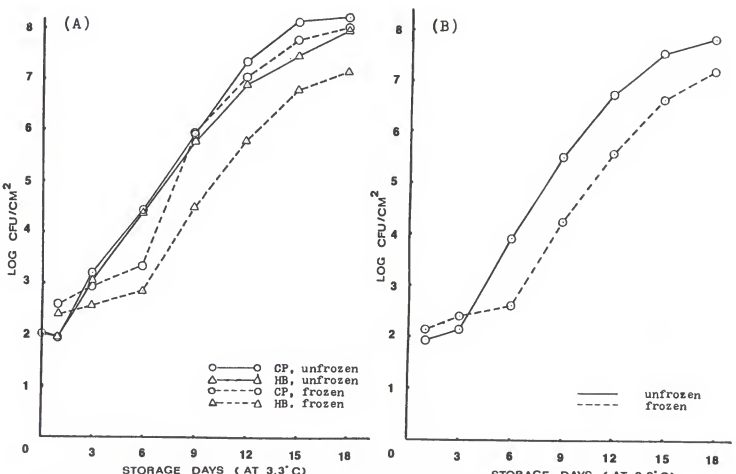
Figure 12 shows that coliforms on breasts in group 5 during the entire storage period were similar to coliforms on the CP group but lower than on the HB group. Hot boning did not cause a lot of initial contamination in this group. An hour of tumbling at 2°C caused some reduction of coliforms and the

Figure 9. Comparison of mesophiles on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 5.



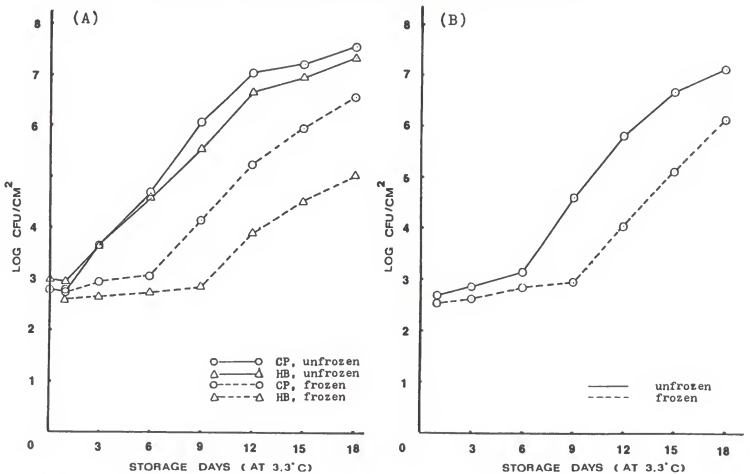
* The different treatments are described in Table 1.

Figure 10. Comparison of psychrotrophs on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 5.



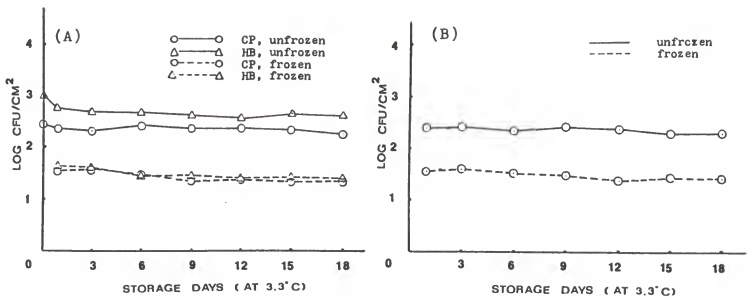
* The different treatments are described in Table 1.

Figure 11. Comparison of 37°C total aerobes on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 5.



* The different treatments are described in Table 1.

Figure 12. Comparison of coliforms on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 5.



* The different treatments are described in Table 1.

low temperature tumbling inhibited the growth of coliforms. Same with in other groups, the amount of coliforms changed very little during the storage period.

2. The microbial quality after freezing

After thawing the frozen samples in group 5, mesophile numbers were similar to the unfrozen ones on the first day. The growth curve in Figure 9B appeared to have a longer lag phase than unfrozen samples and counts were lower on surfaces during storage when compared with the unfrozen breasts. When comparing Figure 9A and 9B, freezing and thawing resulted in CP, HB, and tumbled HB samples having similar numbers of mesophiles on the surfaces right after they were defrosted. However, the HB untumbled and tumbled meat had similar mesophilic counts during the final days of refrigerated storage.

Psychrotrophic counts (Figure 10B) on the frozen-thawed group 5 samples were found to be higher than those on the unfrozen samples on the first three days. Similar results were noted for HB and CP groups. A thawing temperature of 3.3°C was used to defrost the frozen samples. Psychrotrophs could grow after the temperature of meat rose this level. Thawing allowed more apparent growth of psychrotrophs than mesophiles or coliforms. The counts were lower on frozen-thawed samples than on HB untumbled samples from the beginning to the twelfth day of storage and were significantly lower than on CP samples during the whole storage period.

Freezing resulted in lower numbers of 37°C total aerobes for CP, HB, and breasts in group 5. It damaged more higher temperature growing microorganisms than lower temperature growing ones. HB tumbled meat had significantly lower counts than CP samples but had similar counts to HB untumbled samples. It seems that after freezing and thawing of meat, the

microbial change on turkey surfaces caused by tumbling was less important. The effect of freezing and thawing was greater than tumbling.

Coliforms (Figure 12B) significantly decreased after freezing storage and remained constant during the entire refrigerated storage. No differences were discovered among HB tumbled, HB untumbled and CP groups.

3. Effect of polyphosphate with tumbling on microbial quality

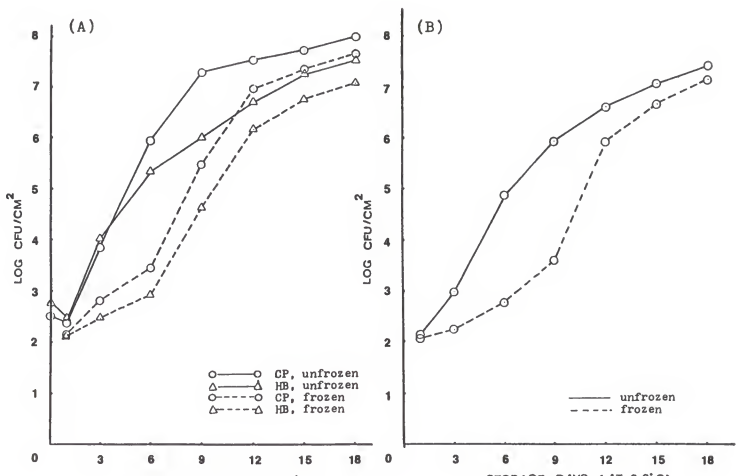
Figures 13, 14, 15 and 16 show the changes of mesophiles, psychrotrophs, 37°C total aerobes, and coliforms on the samples in this group. Tumbling HB samples in polyphosphate solution significantly reduced mesophiles on breast surfaces. This difference between both HB and CP samples was greater than for other treated groups. Psychrotrophs on HB and CP were similar at first. Lower amount of psychrotrophs was found on samples in group 6 and they had significantly fewer psychrotrophs as storage days went by when compared with both CP and HB samples. Significantly fewer 37°C total aerobes were found on group 6 during the whole storage period when compared with HB and CP breasts, which was the same for mesophiles. Coliforms were also less on group 6 than on HB and CP sample and the numbers were steadily during the entire refrigerated storage.

Generally, the decrease in microorganisms on surface of breasts in group 6 was more apparent than for other groups. Both polyphosphate and tumbling resulted in reduced bacteria. The significant decrease in coliforms indicated that this kind of treatment should improve the initial quality of the meat.

When comparing the microbial quality of HB samples after tumbling, polyphosphate solution marinating and tumbling with polyphosphate solution added, mesophilic counts (Figure 17) were similar for all treatments initially. However, after storage tumbled HB samples and polyphosphate solution marinated HB samples had higher mesophiles than those breasts tumbled with polyphosphate solution added. The combination treatment of tumbling with polyphosphate solution gave lower mesophilic counts on HB turkey breast muscles.

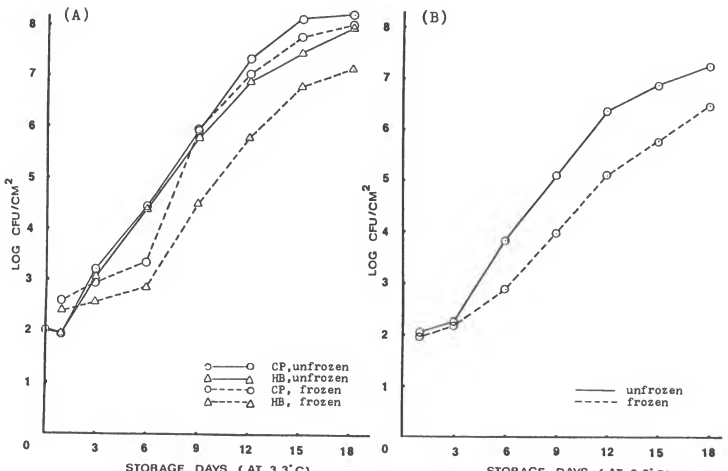
However, when testing for 37°C aerobes (Figure 19), the tumbled meat

Figure 13. Comparison of mesophiles on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 6.



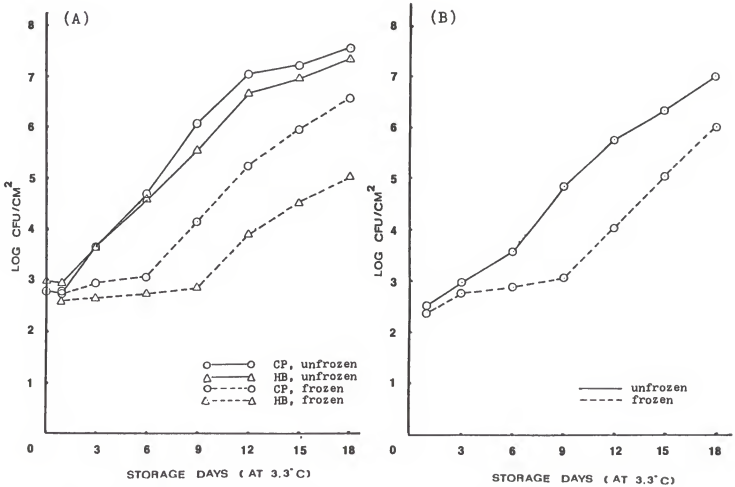
* The different treatments are described in Table 1.

Figure 14. Comparison of psychrotrophs on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 6.



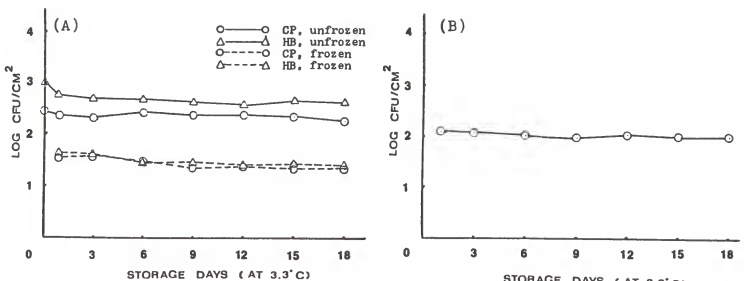
* The different treatments are described in Table 1.

Figure 15. Comparison of 37°C total aerobes on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 6.



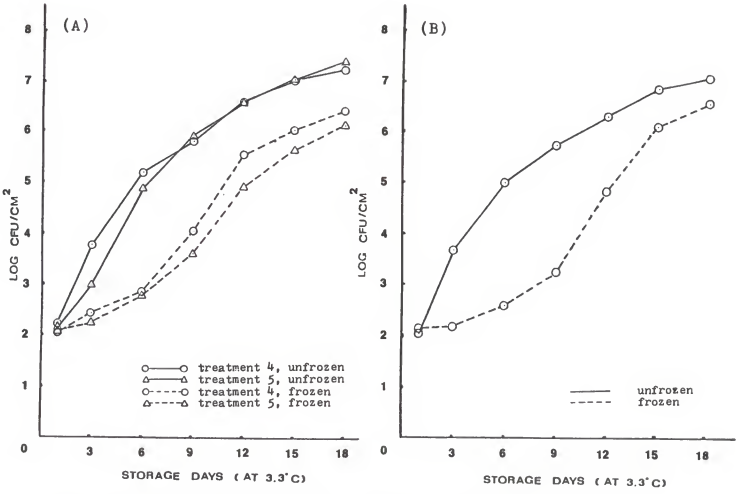
* The different treatments are described in Table 1.

Figure 16. Comparison of coliforms on turkey breast muscles among (A) treatment 1, 2, and (B) treatment 6.



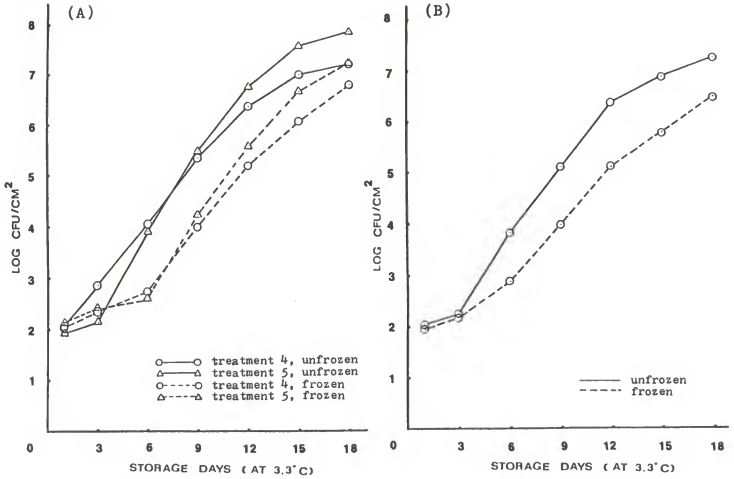
* The different treatments are described in Table 1.

Figure 17. Comparison of mesophiles on HB turkey breast muscles among (A) treatment 4, 5, and (B) treatment 6.



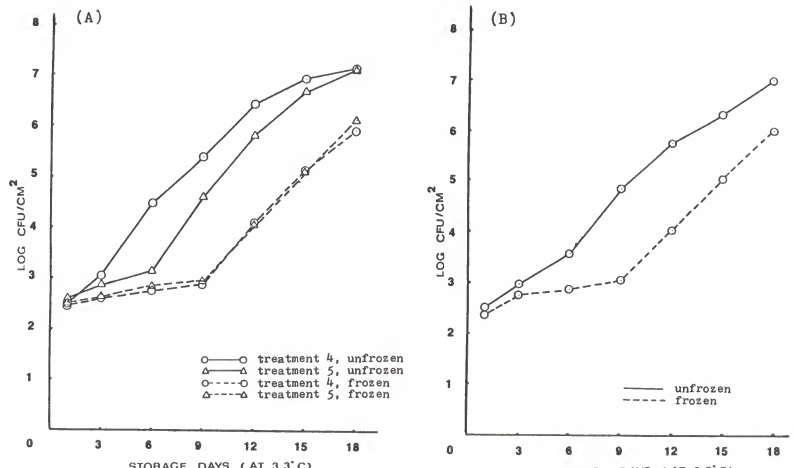
* The different treatments are described in Table 1.

Figure 18. Comparison of psychrotrophs on HB turkey breast muscles among (A) treatment 4, 5, and (B) treatment 6.



* The different treatments are described in Table 1.

* Figure 19. Comparison of 37°C total aerobes on HB turkey breast muscles among (A) treatment 4, 5, and (B) treatment 6.



* * The different treatments are described in Table 1.

with or without polyphosphates had lower counts than the polyphosphate treated meat without tumbling. Polyphosphates did not have a significant effect on inhibition for the 37°C aerobes. Previous literature showed that polyphosphates significantly inhibited growth of pseudomonads but no difference was found for total count on chicken carcasses. Samples with polyphosphate added, with or without tumbling, had lower psychrotrophs on surfaces during the last several days of storage. As incubation temperature increased, tumbling was more effective than polyphosphates.

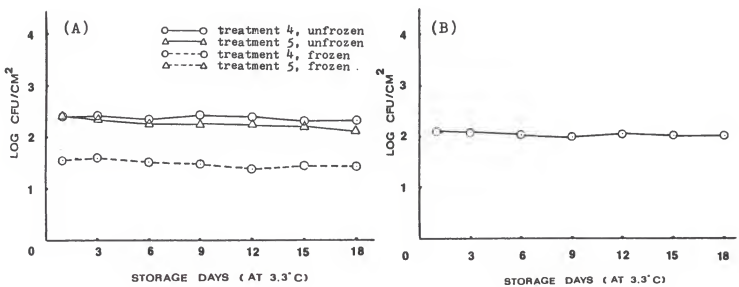
In Figure 20, both tumbled and polyphosphate marinated HB samples had fewer coliforms than did CP samples. The combination treatment of polyphosphate and tumbling gave best results.

4. Effects of polyphosphates, tumbling, and freezing storage on microbial quality

Freezing and thawing made numbers of mesophiles (Figure 13) on surfaces of group 6 similar to those on both HB and CP groups, although they were significantly different before freezing. However, growth rate on group 6 breasts was slower during refrigerated storage. The same conditions were also found for psychrotrophs (Figure 14) and 37°C total aerobes (Figure 15) except that both counts were lower after thawing. All counts after thawing were similar to the counts before freezing on the first day. However, differences were noted as storage days increased. The growth of coliforms was slower on the surfaces after freezing.

When comparing the effect of tumbling, polyphosphate solution marinating and a combination of these two treatments on microbial quality of HB muscles after freezing and thawing (Figures 17, 18, 19 and 20), the

Figure 20. Comparison of coliforms on HB turkey breast muscles among (A) treatment 4, 5, and (B) treatment 6.



* The different treatments are described in Table 1.

differences among these groups were not so apparent as among the unfrozen groups. Mesophiles were similar among these three groups at first, but a higher growth rate was found on tumbled samples. The other two groups were similar during the last several days of storage. The inhibitory effect of either polyphosphate or tumbling was not significant as incubation temperature increased to 37°C. Psychrotrophs showed little differences among these groups at first, but the differences were larger during refrigerated storage. Tumbled samples had the highest count, polyphosphate treated samples the second, and tumbling in polyphosphate solution had the least psychrotrophs.

The effect of polyphosphates seems to be greater than tumbling after frozen storage. This inhibitory effect was more apparent on psychrotrophs than on other higher temperature growing microorganisms. Freezing decreased the effect of tumbling more than of polyphosphates on microbial growth inhibition.

Coliforms significantly decreased on surfaces of polyphosphate treated samples either with or without tumbling. The tumbled HB samples without other treatments showed similar coliforms on surfaces to HB and CP samples. Polyphosphates significantly inhibited contamination and growing of coliforms after thawing. After freezing, tumbling did not show as much inhibition as on unfrozen samples.

CONCLUSIONS

1. Hot-boned turkey breast muscles had higher initial microbial load than conventionally processed turkey breast muscles, but the numbers were still low enough to be microbiologically safe. Microorganisms on hot-boned samples were found to grow slower than on conventionally processed samples.

2. Both salt and polyphosphate marination inhibited the growth of microorganisms on hot-boned turkey breast muscles. Polyphosphate marination had more inhibitory effect on growth of psychrotrophs.

3. Tumbling decreased the initial numbers of microorganisms on hot-boned turkey breast muscles, and significantly prolonged their lag phases.

4. A high number of coliforms was found on hot-boned samples than on conventionally processed samples. All further treatments (salt marination, polyphosphate marination, and tumbling) decreased the numbers of coliforms on hot-boned turkey breast muscles. Freezing significantly decreased the numbers of coliforms on every group of samples.

5. After frozen storage, the microorganisms on every group of breast muscles were found to have longer lag phases, and the refrigerated storage days after defrosting were found to be increased.

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APPENDIX

TABLE A. Mesophilic counts of turkey breast muscles with different treatments under storage at 3.3°C.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
0	2.40^{a}	2.75				
1	2.37^{abc}	2.45^{b}	2.54^{b}	2.21^{cd}	2.14^{d}	2.05^{d}
3	3.85^{ef}	4.01^{e}	3.98^{e}	3.77^{f}	2.98	3.68^{f}
6	5.94	5.32^{g}	5.37^{g}	5.20^{g}	4.87	5.00
9	7.29	6.00^{h}	5.94^{h}	5.81^{i}	5.92^{hi}	5.72^{i}
12	7.52	6.69^{j}	6.50	6.61^{j}	6.60^{j}	6.30
15	7.71	7.23^{k}	7.08^{kl}	7.02^{l}	7.06^{l}	6.83
18	7.98	7.52^{m}	7.36^{n}	7.25^{n}	7.40^{mn}	7.04

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 7 samples except that 0-time value is the mean of 12 samples. means followed by same letters are not significantly different at $p < 0.05$.

** The six treatments are described in Table 1.

TABLE B. Psychrotrophic counts of turkey breast muscles with different treatments under storage at 3.3°C.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
0	2.00^{ab}	2.03^{ac}				
1	1.93^{bd}	1.94^{cd}	2.80	2.08^{d}	1.93^{d}	2.04^{d}
3	3.20^{e}	3.04^{e}	3.30^{e}	2.86	2.14^{f}	2.26^{f}
6	4.42^{g}	4.38^{g}	4.40^{g}	4.06^{h}	3.91^{hi}	3.82^{i}
9	5.91^{j}	5.78^{j}	5.83^{j}	5.36^{k}	5.50^{k}	5.10
12	7.34	6.89^{l}	6.75^{l}	6.37^{m}	6.76^{l}	6.37^{m}
15	8.12^{n}	7.46^{op}	7.33^{o}	6.98^{q}	7.54^{p}	6.87^{q}
18	8.20^{n}	7.93^{r}	7.78^{r}	7.19^{s}	7.82^{r}	7.24^{s}

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 7 samples except that 0-time value is the mean of 12 samples. Means followed by same letters are not significantly different at $p < 0.05$.

** The six treatments are described in Table 1.

TABLE C. Total counts of turkey breast muscles with different treatments under storage at 3.3°C.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
0	2.79^{a}	2.98^{b}				
1	2.74^{acd}	2.93^{b}	2.80^{c}	2.49^{e}	2.69^{de}	2.52^{e}
3	3.66^{f}	3.64^{f}	3.43^{g}	3.06^{g}	2.85^{g}	2.97^{g}
6	4.68^{h}	4.58^{h}	4.31^{i}	4.48^{hi}	3.14	3.58
9	6.06	5.52	5.38^{j}	5.39^{j}	4.60	4.84
12	7.03	6.65	6.32^{k}	6.41^{k}	5.81^{l}	5.76^{l}
15	7.20	6.92^{m}	6.98^{mn}	6.93^{m}	6.68	6.32
18	7.55	7.32	7.09^{no}	7.15^{o}	7.11^{o}	7.00^{o}

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 7 samples except that 0-time value is the mean of 12 samples. Means followed by same letters are not significantly different at $p < 0.05$

** The six treatments are described in Table 1.

TABLE D. Coliform counts of hot-boned and conventionally processed turkey breast muscles under storage at 3.3°C.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
0	2.43^{a}	3.01				
1	2.37^{ab}	2.76^{d}	2.26^{bce}	2.43^{bf}	2.40^{bg}	2.09^{ch}
3	2.31^{ai}	2.67^{d}	2.21^{eij}	2.42^{fi}	2.41^{gi}	2.07^{hj}
6	2.42^{ak}	2.68^{d}	2.21^{ep}	2.36^{fk}	2.36^{gk}	2.02^{h}
9	2.38^{al}	2.61^{dm}	2.24^{es}	2.33^{fl}	2.43^{gl}	1.98^{h}
12	2.38^{an}	2.54^{m}	2.19^{eo}	2.35^{fn}	2.40^{gn}	2.04^{ho}
15	2.33^{ap}	2.63^{dm}	2.20^{ep}	2.31^{fp}	2.32^{gp}	2.00^{h}
18	2.26^{aqr}	2.60^{m}	2.18^{eq}	2.25^{fqr}	2.33^{gr}	2.00^{h}

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 7 samples except that 0-time value is the mean of 12 samples. Means followed by same letters are not significantly different at $p < 0.05$.

** The six treatments are described in Table 1.

TABLE E. Mesophilic counts of turkey breast muscles with different treatments after five months frozen storage.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
1	2.14^{a}	2.11^{a}	2.52	2.05^{a}	2.08^{ab}	2.15^{ac}
3	2.80^{d}	2.47^{e}	2.92^{d}	2.41^{e}	2.23^{bf}	2.18^{cf}
6	3.45^{g}	2.91^{h}	3.32^{g}	2.86^{h}	2.78^{h}	2.60
9	5.47	4.63	4.90	4.05	3.60	3.24
12	6.94	6.16	6.01^{i}	5.56	5.91^{i}	4.84
15	7.32	6.74^{j}	6.25	6.04^{k}	6.66^{j}	6.10^{k}
18	7.66	7.08^{l}	6.73	6.42^{m}	7.14^{l}	6.56^{m}

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 5 samples. Means followed by same letters are not significantly different at $p < 0.05$.

** The six treatments are described in Table 1.

TABLE F. Psychrotrophic counts of turkey breast muscles with different treatments after five months frozen storage.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
1	2.59	2.39^{a}	2.89^{b}	2.05^{cd}	2.12^{c}	1.94^{d}
3	2.93^{e}	2.56^{af}	2.97^{be}	2.32^{g}	2.40^{fg}	2.18
6	3.32	2.84^{h}	3.10	2.75^{hi}	2.61^{i}	2.88^{h}
9	5.93	4.47^{j}	4.35^{jk}	4.00^{l}	4.24^{k}	3.98^{l}
12	7.03	5.79^{m}	5.63^{m}	5.20^{n}	5.59^{m}	5.10^{n}
15	7.75	6.78^{o}	6.61^{o}	6.07	6.66^{o}	5.78
18	7.98	7.14^{p}	7.03^{p}	6.79	7.20^{p}	6.47

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 5 samples. Means followed by same letters are not significantly different at $p < 0.05$.

** The six treatments are described in Table 1.

TABLE G. Total counts of turkey breast muscles with different treatments after five months frozen storage.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
1	2.77^{a}	2.59^{bc}	2.61^{bd}	2.46^{ef}	2.52^{bg}	2.38^{e}
3	2.92^{ah}	2.65^{ci}	2.74^{dij}	2.59^{fi}	2.61^{gi}	2.76^{ik}
6	3.04^{hl}	2.71^{cmo}	2.91^{jln}	2.75^{mp}	2.83^{mnq}	2.88^{kn}
9	4.14	2.83^{or}	3.35	2.88^{pr}	2.94^{qrs}	3.04^{s}
12	5.23	3.89^{t}	3.94^{tu}	4.10^{u}	4.05^{tu}	4.02^{tu}
15	5.94	4.51^{v}	4.62^{v}	5.16^{w}	5.11^{w}	5.04^{w}
18	6.55	5.01^{x}	5.13^{x}	5.91^{y}	6.12^{z}	6.00^{yz}

* Each value is the mean $\log_{10}$ Colony forming Unit/cm^2 of 5 samples. Means followed by same letters are not signifncantly different at $p < 0.05$.

** The six treatments are described in Table 1.

TABLE H. Coliform counts of turkey breast muscles with different treatments after five months frozen storage.*

DAY	TREATMENTS**					
	1	2	3	4	5	6
1	1.54^{ab}	1.63^{ac}	0.87^{d}	D	1.57^{ae}	ND
3	1.57^{bf}	1.59^{cfg}	0.80^{d}	D	1.60^{ef}	D
6	1.47^{bhi}	1.43^{ghj}	0.74^{d}	D	1.52^{ehk}	D
9	1.33^{il}	1.44^{gjl}	D***	ND	1.48^{ekl}	ND
12	1.36^{im}	1.38^{jm}	D	D	1.39^{km}	ND
15	1.31^{in}	1.40^{jn}	ND	ND	1.45^{ekn}	D
18	1.31^{io}	1.39^{jo}	D	D	1.44^{eko}	ND

* Each value is the mean $\log_{10}$ Colony Forming Unit/cm^2 of 5 samples. Means followed by same letters are not significantly different at $p < 0.05$.

** The six treatments are described in Table 1.

*** D = detected.

ND = not-detected.

MICROBIOLOGICAL QUALITY OF HOT-BONED TURKEY BREAST MUSCLES

by

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ABSTRACT

Mesophiles, psychrotrophs, 37°C total aerobes, and coliforms were detected on hot-boned, salt-marinated hot-boned, polyphosphate marinated hot-boned, tumbled hot-boned, polyphosphates with tumbling treated hot-boned, and conventionally processed turkey breast muscles during the eighteen refrigerated storage days before and after freezing. Hot-boned samples had higher microbial counts immediately after deboning than conventionally processed samples except that psychrotrophs on both samples were similar. Lower numbers of microorganisms were found on hot-boned samples at the end of refrigerated storage period. Both salt and polyphosphate marination decreased the numbers of microorganisms on hot-boned samples during refrigerated storage although higher or similar initial microbial loads were found when compared to hot-boned and conventionally processed samples. Salt marination was found to have more inhibitory effect on growth of mesophiles. Polyphosphate marination was found to have more inhibitory effect on growth of psychrotrophs. Tumbling decreased the initial microorganisms on hot-boned samples, and significantly prolonged their lag phases. The decrease of microorganisms on hot-boned samples with polyphosphate and tumbling treatment was more apparent than any other groups. The number of coliforms on every group of meat changed very little during the entire refrigerated storage. A higher number of coliforms was found on hot-boned than on conventionally processed samples. All further treatments decreased the numbers of coliforms on hot-boned samples, especially for polyphosphate with tumbling treatment. Freezing caused the microorganisms on every group of breast muscles have longer lag phases and increased the refrigerated storage days after defrosting. Number of coliforms significantly decreased because of

freezing, especially for salt marinated, polyphosphates marinated, and polyphosphates with tumbling treated breast muscles.