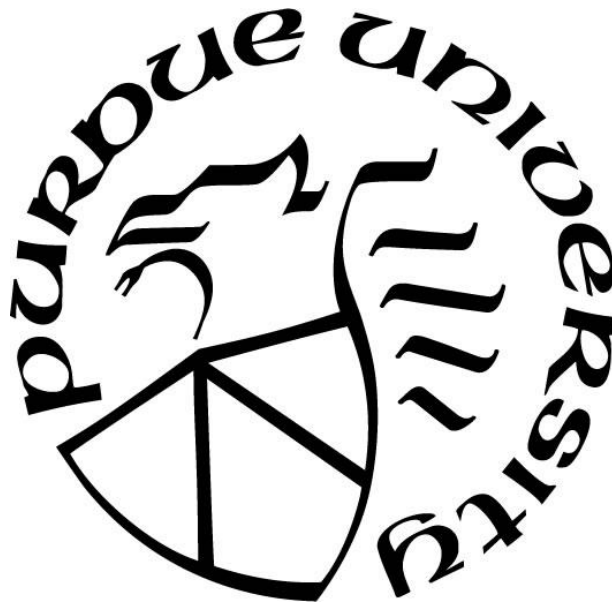# IMPACT OF ANTIMICROBIAL CARCASS WASHES ON BEEF TRIM QUALITY IN THE PRODUCTION OF BEEF FRANKFURTERS

by

Emily Ford

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THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Stacy Zuelly, Chair

Department of Animal Science

Dr. Brad Kim

Department of Animal Science

Dr. Haley Oliver

Department of Food Science

Approved by:

Dr. Ryan Cabot

Dedicated to Hinley and Briar Ford

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ABSTRACT

This objective of this study was to determine the impact of antimicrobial carcass washes on beef trim quality in the production of frankfurters. Twenty-four beef carcasses were randomly applied a different antimicrobial wash treatments (TRT) during the harvest procedure: 82° C water (CON), peroxyacetic acid (PAA), or lactic acid (LA). Beef carcasses were analyzed for microbial counts and carcass pH. Frankfurters were produced using carcass trim at two different batter temperature processes (PROC): 4°C (CP) or 21°C (HP). Frankfurters were analyzed for cook loss, emulsion stability (ES), color (Minolta L*, a*, b*) over 60-day storage, purge loss, texture, and sensory analysis. LA carcass had a lower pH (6.36; $P<0.001$) 30 min post wash compared to other wash treatments. Frankfurters produced from CON trim had the highest ES water ($P<0.0001$) and ES fat ($P<0.0001$) separation where the LA and PAA treatments were not significantly different ($P>0.05$). The HP frankfurters had less ES water ($P<0.0001$) and ES fat separation ($P<0.0001$) when compared to CP. However, the CP had a higher cook yield ($P=0.002$). The HP frankfurters had higher internal and external L* values ($P<.0001$; $P<.0001$, respectively). The CP frankfurters had a higher a* (redness) internal color values ($P<.0001$). However, the HP frankfurters had a higher external a* value ($P<.0001$). The HP frankfurters displayed higher internal and external b* (yellowness) values ($P<.0001$). Sensory results displayed the CP frankfurter to have an increase in hardness ($P=0.004$), a decrease in cohesiveness ($P=0.03$) and an increase in juiciness ($P<.0001$). Texture analysis hardness ($P=0.009$) and chewiness ($P=0.01$) results showed the CON frankfurters were significantly harder than PAA ($P<0.05$), while LA were not different from CON or PAA frankfurters ($P>0.05$). The CP frankfurters were found to have a decrease in springiness ($P=<.001$) and cohesiveness ($P=0.03$). There was a significant difference in microbial reduction of pre to post

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wash petri film counts for all treatments (Log$_{10}$CFU/mL) of aerobic plate count ($P= <0.0001$),

E.*coli* coliform ($P= 0.0002$), yeast ($P=0.04$) and mold ($P= <0.001$). TRT was found to be

significant for APC ($P=0.06$) and yeast ($P=0.004$). Overall, our research indicated antimicrobial

wash treatments have little effect on frankfurter quality and displayed viable methods for

reducing microbial growth on beef carcasses.

Key words: frankfurter, antimicrobial wash, beef trim, emulsion stability

CHAPTER 1. LITERATURE REVIEW

Introduction

According to National Hotdog and Sausage Council in 2018 more than 3 billion dollars in hotdogs were sold in U.S. markets. With a large demand of the comminuted meat products the meat industry strives to produce wholesome products for their consumers daily. Many factors like raw materials, ingredient functionality and varying production techniques play a role the products quality and appearance. Additionally, the USDA strives to inhibit possible pathogenic bacteria from entering the food systems and many food safety measures are taken for consumer insurance. There is much research related to different bacteria lethality techniques and decontamination practices however, little research has determined if those intervention practices have downstream effect on the further processed products like hotdogs, smoked sausage and other comminuted meat products.

Fresh Meat Quality

Extensive research has investigated meat quality and the attributes that can affect color, and palatability (tenderness, juiciness, and flavor). Such attributes commonly determine the end use of the meat source and its marketability to consumers therefore, they meat quality attributes contribute greatly to the overall economic impact of fresh and processed meat products.

Meat color is easily assessed by consumers and, as such, consumers purchasing decisions are significantly influenced by the color of meat products, as consumers associate discoloration to determine if a product is fresh or wholesome (Mancini & Hunt, 2005). Meat color is primarily determined by the sarcoplasmic protein myoglobin (Aberle & Forrest, 2001). Myoglobin has a heme ring, with iron found in the center with 6 ligands and a globin attached. The various

oxidative states of the iron, and the molecule attached to the 6th ligand of iron determine the color observed (Aberle & Forrest, 2001). These can be impacted by extrinsic factors such as light, oxygen, heat, and processing ingredients. Many factors must be considered that impact meat color as Carpenter et al., (2000), reported a correlation of visual scores and likelihood of purchasing was found in steaks and patties of surveyed consumers.

Meat tenderness is impacted by sarcomere length, connective tissue content, and post mortem proteolysis (Aberle & Forrest, 2001). As sarcomeres increase in length, the myofilament overlap is reduced, resulting in improved tenderness (Savell et al. 1992). Beef tenderness decreases with advanced age associated with collagen content and cross-linkages (Savell et al., 1992; Locker, 1960). Finally, postmortem proteolysis results in degradation of muscle proteins resulting in improved tenderness (Aberle & Forrest, 2001). According to Miller et. al., (2001) seventy-eight percent of all consumers were willing to pay for steak if they were guaranteed tender in a retail setting. The consumer study also shows that an increase in consumer acceptability values are directly correlated with Warner-Bratzler shear force values (WBS) (Miller et al., 2001). Additionally, Destefanis et al., (2007) reported a relationship of consumers perception and beef tenderness finding WBS values of >52.68N and <42.87N of tough and tender meat classification. Therefore, cuts that are of greater tenderness are generally used for whole muscle products (steaks and chops) and are of significantly greater value, however, cuts of reduced tenderness must be processed to meet consumer demands of palatability.

Juiciness is determined by the fat and water found within the product. Fat will melt when cooked, creating juiciness when consumed. Therefore, the amount of fat present, particularly intramuscular fat/marbling is very important to sensory juiciness (Aberle & Forest, 2001). Water molecules are attracted to proteins due to their charge interactions as 75% of meat is comprised

of water. Water holding capacity (WHC) is simply the ability for meat proteins to hold on the

bound or free water throughout meat processing procedures like cooking, freezing, thawing,

mincing, curing, and smoking (Hamm, 1986). Water is a dipolar molecule and has different

fractions of free, immobilized and bound water that impact water loss. Offer & Knight (1988)

reported on average fresh product weight loss can be 1-3%. Manipulation of myofibular proteins

can increasing the amount of immobilized water in a meat system by altering the net charge of

the proteins (Lonergan, 2005). The net charge effect occurs by the influence of meat pH is

reached the isoelectric point (pI) of the meat system around 5.2 causing the net charge of protein

to be zero, this allows the proteins that are normally attracted to each other to be more available

to other molecules like water (Lonergan, 2005; Aberle & Forrest, 2001). Meat processors strive

to obtain water with the meat as much as possible to decrease processing defects and major water

loss of meat products.

Consumer acceptance is defied by palatability at the point of consumption (Webb &

O'Neill, 2008). In order to group carcass by potential palatability indicators, the beef industry

has used the USDA beef quality grading system, since 1925. This grading system has been

updated over the years to focus on marbling and maturity as these factors impact palatability

(USDA, 1996). Jeremiah et al.(2003) reported 12-14% of all variation in palatability traits as

intramuscular fat directly affected juiciness and flavor whereas tenderness was affected

indirectly when major beef muscles and cooking composition were observed. Many other factors

have been studied to affect beef palatability like animal breed, nutrition, environment, fatty acid

composition and lipid oxidation.

Fresh meat quality defects, such as pale, soft, and exudative (PSE) or dark, firm, and

dry/dark cutters (DFD) can impact a further processed product. PSE is described meat that is

soft, has loose muscle structure, and grainy texture (Aberle & Forrest, 2001). PSE is caused from

rapid pH decline when the muscle is warm causing protein denaturation. Therefore, the lack of

protein functionality causes a decrease in WHC. Li & Wick, (2001) reported sausages made

from PSE meat displayed less rigidity and was improved by mechanically deboned turkey

extract. PSE has shown to have reduced protein functionality and have a greater water loss in

cooked meat gels when different heating rates were applied (Camou & Sebranek, 1991) The

other spectrum of poor meat quality is DFD, which is obtain at a higher pH of 6.4 and above for

pork and beef carcasses. DFD is caused by pre harvest stress conditions or from animals

susceptible to stress(Aberle & Forrest, 2001). In summary, PSE will have a downstream effect

on further processed products as it will cause an increase in protein denaturation and reduce

protein extraction causing greater water loss from cooked meat gels (Gordon et al., 1992).

Fat Quality

Fat is an important ingredient in processed meat products as it imparts flavor, tenderness,

and juiciness attributes that appeal to the consumer. The degree of saturation from animal fat

determines the characteristics of hardness, melting point, oxidative stability and flavor. Pork fat

is generally softer in texture, lower melting point and has a greater chance of lipid oxidation

because is it an unsaturated in composition (Lonergan et al., 2013). Ruminant fat tissue is more

saturated in nature has a higher melting temperature and is less susceptible to lipid oxidation

(Wood et al., 2004). Unsaturated fats are more susceptible to oxidative rancidity because of the

number of double bonds that oxygen can be attracted to causing oxidative rancidity (Wood et al.,

2004).

The USDA states sausages can have up to 30 percent fat in formulation. During

emulsification the fats are affected by chopping temperature and speed. The fat source of the

meat greatly depends on the end temperature of the batter to optimize emulsion stability

(Knipe,1987) . If the emulsion becomes unstable it can cause the fat to disperse from the meat

matrix in turn can cause fatting out during the heat cycle of the manufacturing process. Youssef

& Babbut (2010) studied the effects of using a pre-emulsified canola oil as a replacement for

beef fat concluded reducing fat in meat batters resulted in higher cook loss, softer texture and but

no effect on color. Additionally, Ambrosiadis et al., (1996) studied the effect of vegetable oil

replacers in frankfurter style sausages concluded vegetable oils can be replaced up to 19.5-27.5%

with corn seed or sunflower oil produced product most like the control. Meat from pigs fed a

high levels monounsaturated diet reported to be less desirable when producing frankfurters

compared to control of conventional soybean diets (Shackelford et al., 1991).

Emulsions

An emulsion is dispersing one immiscible liquid into another in order to obtain an

emulsion; an emulsifier is added to combine the two liquids. A meat emulsion differs from a true

emulsion as is uses salt soluble myofibular proteins as an emulsifying agent to combine the lean

meat, fat, water and other non-meat ingredients into a meat batter (Longergan, 2013). Salt is used

to assist in the extraction of the salt soluble proteins, which increase the stability of the emulsion.

Chopping or agitation of the meat batter is used assist in releasing proteins and increase their

functionality by coating fat particles, allowing an emulsion between fat and water to occur.

Forming a stable meat emulsion is important when developing comminuted meat products as

consequences in sensory characteristics and physical appearance can be affected (Gordon et al.,

1992). Emulsion or batter stability is the action of all ionic connections to water to remain stable

during the heat cycle. Batter stability is generally influenced by heating rate, cooking

temperature, the biochemical state of meat, the amount and type of ions present and pH (Gordon

et al., 1992). When forming a meat emulsion many factors can inhibit the stability the meat matrix such as pH, protein extraction and temperature.

Emulsion Stability and pH Effects

The pH of raw meat is species dependent, but generally ranges from 5.2-7.0 can affect fresh and processed meat quality. Meat pH is a major determinate to the interactions of muscle proteins and water due to the net charge effect (Lonergan, 2013). Muscles with a higher pH have an increase in WHC due to the net charge effect as it relates to the amount of charges a particular protein possesses. The isoelectric point (pI) of a protein occurs when the pH of the protein has a zero-net charge (Lonergan, 2013), meaning the side chains have no charge for water molecules to bind with. In general, the pI for fresh meat is at a pH of 5.2 (poorest water binding) there is an increase of water binding ability of those proteins that are greater or lower than pH 5.2. Commonly higher pH meat sources like bull or sow pre-rigor meat can be used in sausage type products as it naturally has a higher pH. When meat is in a pre-rigor state increases the can natural ability hold more water without the addition of ingredients like salts or phosphates.

Furthermore, when the pH properties are applied to processed meat products the pH can cause differences when forming a comminuted meat product. Researchers found the pH can cause textural differences of meat products due to the water binding abilities below 5.0 pH conditions can be used to extract more proteins resulting in a firmer comminuted meat product (Matulis, et al., 1995). However, if pH is very low, protein denaturation can be induced causing problems on the further processed products for example poor emulsion stability (Hamm, 1986). A study investigating the functional stability of normal and high pH beef observed the meat pH affected sarcoplasmic and myofibrillar protein stability as well as increased WHC (Zhang et al.,2005). Also, Zhang, et al. (2005) concluded cooked batter of higher pH meat displayed a

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higher torsion stress, yield and emulsion stability than normal pH. Meat pH is an important

factor when producing a stable meat emulsion due to the positive and negative effects it can

cause on meat emulsions.

Protein Extraction and Emulsion Stability

Protein extraction is a critical component of forming a meat emulsion. Proteins are used

as the main source to combine the immiscible fat and water in the meat batter as well as increase

emulsion stability. Salt soluble myofibrillar proteins are extracted with the addition of salt and

water once disrupted from their fibrous structure (Aberle & Forrest, 2001). The proteins will

form a gel matrix when salt causes swelling of myofibrillar proteins and favorable ionic

conditions, in turn forming a viscous matrix to act as an emulsifying agent (Aberle & Forrest,

2001). The proteins are drawn to fat globules helping to form a stable membrane in the raw state

and during a heat cycle the proteins will coagulate immobilizing the fat and water (Gordon et al.,

1992). Additionally, when forming an emulsion the batter temperature increases in the

comminution process to increase the emulsifying properties of fat, protein and water research

shows temperature has an increasing effect of the ability to bind meat pieces of 45- 80° C (Siegel

& Schmidt, 1979).

Sodium chloride (NaCl) is a non- meat ingredient commonly used in further processed

products that imparts flavor, increases protein extraction, inhibits microbial growth and increases

WHC properties. With the addition of sodium chloride (NaCl) more protein extraction occurs

causing the salt soluble myofibrillar protein to increase due to salt's ionic strength. The chloride

ion causes the protein to swell and disrupt the myofibrillar structure (Offer & Trinick, 1983). The

use of salt and phosphate increase the myosin binding properties yielding in a greater gel

structure and increase water holding capacity (Siegel & Schmidt, 1979). The addition of sodium

chloride positively affects the emulsion stability of a product by increasing protein functionality in the emulsion matrix.

Temperature Effects of Emulsion Stability

The amount of heat applied to meat protein or emulsion can positively and negatively affect the stability. According to Siegel & Schmidt (1979), temperatures lower than 45°C displayed an abscess of myosin binding ability of meat pieces where as in increase in temperature of 80°C produced a linear binding ability of meat proteins. Furthermore, a thermal denaturation study of actin and myosin proteins displayed 43°C as the maximum temperature for change in protein conformation (Jacobson & Henderson, 1973). Stronger more cohesive gels and emulsion stability increased when slower cooking rates were applied to emulsified meat products (Barbut & Mittal, 1990). Emulsion instability caused excessive fat and water loss when high fat chopping temperatures were used (Lee et al, 1985).

Frankfurter Sensory

The quality and sensory characteristics of a frankfurter is dependent on many processing factors, ingredients, salt concentration and fat levels. Lee et al., (1987) observed an increase in chopping times for 3.5 to 6.5 min had an increase in sensory scores of firmness, chewiness and elasticity. Moreover, ingredients can affect the texture of the product according to (Matulis et al., 1995) who investigated sensory characteristics of varying salt, pH, and fat levels the study reported that as the salt concentration increased the hardness increased. Also, Matulis et al., (1995) found that as the pH increased to approximately 6.3, the hardness of the frankfurter decreased also, when there is an increase in salt concentration levels the juiciness increased when tested by a trained sensory panel. In a study observing commercially available frankfurters

observed fat content positively correlated with juiciness and negatively correlated with intron hardness, fracturability and area measurements (Matulis et al, 1995). Moreover, when fat percentage is lowered in a formulation sensory attributes can change, more specifically lower fat products were considered more tender than those with higher fat concentrated frankfurter formulations (Matulis et al.,1995). Lee et al. (1987) showed frankfurters produced with a softer fat were perceived as less firm and chewy when evaluated by a consumer panel. Furthermore a study looking at the effects of rigor state, salt levels and phosphate levels of frankfurters determined juiciness was not affected by use of phosphate however frankfurters with 0.375% phosphate were firmer than without (Puolanne & Terrell, 1983). Many factors affect sensory attributes as ingredients and formulation changes directly affect the sensory and palatability traits of frankfurter type sausages.

Frankfurter Processing Techniques

Quality and sensory characteristics of a comminuted meat product are closely related to the type of processing techniques used for manufacturing. A processing technique commonly used in commercial frankfurter production is called pre-blending. The pre-blending process combines cure ingredients, salt, and water to meat and is allowed it to sit for 24-48 hours before chopping. This processing technique provides time for meat to combine extensively with other ions causing the meat and ingredients to be more homogenized (Schmidt, 1984). Mechanical action or chopping is a very important step in producing comminuted meat products, chopping allows interactions to increase while reducing the particle size to form a stable meat batter. Bowl choppers are used to decrease particle size of meat with very sharp knives for maximum contact with meat forming a meat batter. Bowl choppers increase the batter temperature and

homogenize the meat batters (Schmidt, 1984). However, over chopping is also known to be detrimental to a meat batter as it causes disruption of the emulsion (Jones & Mandigo, 1982).

Product quality is dependent on the temperature of processing conditions, chopping time and final batter temperature (Gordon et al., 1992). Additionally, temperature increase of a meat batter is important when forming a stable emulsion thus affecting the fat dispersion of the meat emulsion matrix. A study focusing on different endpoint chopping temperatures of 10,16, 22, 28°C concluded batters with end chopping temperatures greater than 22°C had a higher cook loss than the other treatments (Jones & Mandigo, 1982). Earlier work by Townsend et al. (1968a; 1968b) suggested that the melting characteristics of meat fats could be the basis for differences in the temperatures at which the meat formulas should be emulsified. Later work discovered the stability of beef and pork emulsions suggested that the melting characteristics of fats, rates and extent of temperature rise, and the rates of dispersion interrelate in the emulsion stability (Swift et al., 1968). Sutton et al., (1995) concluded endpoint chopping temperatures at peak of 15°C and below produced the most stable product in reduced fat high moisture beef frankfurters.

Microorganisms

Microorganisms are abundantly found in all environments and are harbored on livestock species used for meat production and, therefore, may potentially contaminate the carcass during slaughter process through cross contamination of product surfaces, handling equipment, and storage (Lahr, 2001). For this reason, antimicrobial interventions are required at the point of harvest. Microorganisms are known to cause spoilage or can be pathogenic if microbial interventions fail. The bacteria common for meat spoilage are *Pseudomonas, Acinetobacter/Moraxella, Aeromonas, Altermonas putrefaciens, Lactobacillus, and Brochonthrix thermosphacta* (Kotula and Kotula, 2000). Pathogenic bacteria in concern include; *Escherichia*

coli O157:H7,O26, O45,O103,O111,O121, and O145. Salomella spp., Listeria monocytogenies, Campylobacter, Clostridium botulinum, Clostridia perfringens, Staphycoccus aureus, and Bacillus cereus (Huffman, 2002). Pathogenic organisms can cause extreme illness if people are infected and are a major concern in food production.

Numerous food borne illness outbreaks have made the (USDA) and the Food Safety Inspection Service (FSIS) increase their efforts of reducing the pathogens from entering the food systems. Insuring food safety safe handling practices, sanitation standard operating procedures (SSOP) and hazard analysis critical control point (HACCP) plans are mandated by the USDA-FSIS. Processing plants must comply with the USDA-FSIS microbial lethality and food safety standards when producing meat products. The USDA has approved the use of many carcass decontamination methods to ensure food safety. During the harvest process microbial intervention steps are critical in reducing microbial contamination, as it is known to improve shelf life and safety of meat (Huffman, 2002). Factors affecting bacterial attachment to meat surfaces depend on temperature, pH, and culturing methods (Firstenberg-Eden, 1981). Additionally, research has shown the most effective technique is a combination of multiple interventions is performed sequentially as a "multiple hurdles" effect. (Belk, 2001) According to Hardin et al. (1995), when beef carcasses are first washed with 35°C water and treated with an organic acid was more effective than a single acid wash treatment or knife trimming, observing the multiple hurdle approach is more effective.

Types of Microbial Washes

Skeletal muscle from an animal is initially sterile before exposed to potential bacteria contamination, particularly during the harvest process. Microbial interventions are commonly used, and often required, in order to comply with the USDA-FSIS microbial reduction standards.

There are many different microbial interventions applied to carcasses during the harvesting process including dehairing, hot water washes, organic acid, oxidizer antimicrobial rinses, and sanitary knife trimming

The USDA- FSIS acknowledges hot water (>74° C) yields a sanitary effect on beef carcasses (USDA-FSIS, 1996). Studies have shown when beef carcasses were sprayed with hot water (94°C) before and after the final tap water wash, the carcasses displayed a significant log reduction in aerobic plate counts before the final tap water wash of 1.3 $\log_{10}cm^2$ whereas samples sprayed after the final tap water wash displayed 0.8 $\log_{10}cm^2$ reduction (Barkate, Acuff, Lucia, & Hale, 1993). Additionally, a study spraying beef carcasses at 95°C at a high pressure of 24 psi at a distance of 12.5cm for 5 seconds showed a significant log reduction in total coliform, thermotolerant coliforms, *Salmonella* Typhimurium and *E. Coli* O1057:H7 (Acuff et al., 1996). Hot water rinses are widely used in industry as an antimicrobial intervention for beef carcasses and can be easily implemented for small processors as an affordable intervention option.

Organic acids such as acetic, citric, and lactic acids are widely studied antimicrobial agents used in the application of beef carcasses (Belk, 2001). The USDA-FSIS has approved the use of organic acid solution of 1.5-2.5% organic acids are very effective in the lethality of a microorganism (USDA FSIS, 1996). Organic acids disrupt the cytoplasm of the cell by acidifying the cell system and releasing a proton. More specifically, interrupting the nutrient transport and energy generation of a cell by altering the intracellular pH when the pH of cell is higher than the pKa of the acid wash, ultimately affecting microbial growth (Booth, 1985; Wheeler et al., 2014).

Lactic acid is the most common organic acid in the meat industry for its advantages of decontamination and cost (Wheeler et al., 2014). Hardin et al. (1995) reported a significant

difference in the reduction of *E. coli* O105:H7 within the 400 cm^2 infected area when treated with lactic acid for the outside round and brisket areas than other treatments of trimming, water washing and organic acid treatment or fecal contamination on beef carcasses were compared. Additionally, a study reported a 10 to 30 second spray of a 2% lactic acid treatment resulted in a 1 to 3 log reduction of sheep and goat carcasses (Dubal et al., 2004). Low pH acid washes are used to decrease microbial growth however does the microbial wash treatments alter the pH of beef trim or any final products from the raw materials. Kang, et al. (2001) studied the effects of treated beef trim with 2.0% lactic acid wash at 30 psi for 3 passes displayed a significantly different pH of around 5.78 ± 0.4 of beef patties compared to the control. Additionally, Hardin et al. (1995) determined a significant difference in surface pH of beef carcass inside round, outside round, brisket and clod carcass regions when treated with a 2% lactic acid antimicrobial wash treatment. In conclusion, lactic acid interventions are very effective in controlling microbial lethality for multiple species and varying treatment applications.

Oxidizer antimicrobials like peracetic acid or peroxyacetic acid are approved microbial washes for beef carcasses (FDA, 2003). In the meat industry 400 ppm is the maximum allowed concentration for fresh beef carcasses, however 200 ppm is generally applied (Wheeler et al., 2014). Oxidizer antimicrobials are very effective in killing microbes as it targets within the cell initiating electrons to be transferred to the cell much faster causing a rapid death (Wheeler et al., 2014). Ransom et al. (2003) reported a 1.4 log reduction of inoculated beef carcass tissue with the use of 0.02% peroxyacetic acid spray. A 0.7 log reduction in *E. coli* O1057: H7 was reported when 200 ppm and a 0.2 log reduction of E. coli O1057: H7 with a 500 ppm peroxyacetic acid wash treatment was applied to beef trim (Ellebracht et al., 2005). Peroxyacetic washes are an effective way to decontaminate beef carcass and trim surfaces.

Overall microbial washes have been widely researched in controlling microbial contamination using multiple intervention treatment methods to comply with the UDSA-FSIS microbiology lethality standards. Although the impact of antimicrobial washes on safety is extremely important, these interventions pose a potential risk to the fresh and processed meat quality, particularly in relation to meat color and pH.

Antimicrobial washes have potential color effects of meat color and people in the meat industry have raised some concerns of discoloration in beef carcasses (Huffman, 2002). However, these concern varies as reports from Bell et al. (1986) show no discoloration in beef when treated with 1.2% acetic acid treatment for 1 min. versus a low concentration of lactic acid 0.6% sprayed for 10 minutes caused a significant change in color compared to controls. Additionally, hot water rinse did not generate any permanent discoloration when a carcass wash of 80°C water was applied (Castillo et al., 2002).

In conclusion, fresh and processed meat quality is very important to the meat industry. Research has shown there are multiple factors such as protein functionality, formulation, and processing techniques that can affect products and their overall quality. Specifically, pH playing a major role in the quality of fresh and processed meats as it can positively and negatively alter many functional properties of proteins and water holding capacity in meat products alike. Antimicrobial treatments are necessary to improve food safety, however, there is a major concern in the use of low pH washes could be detrimental to meat quality. This poses the question whether the low acid antimicrobial washes can have a downstream effect on quality of emulsified products such as frankfurters.

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CHAPTER 2. IMPACT OF ANTIMICROBIAL CARCASS WASHES ON BEEF TRIM QUALITY IN THE PRODUCTION OF BEEF FRANKFURTERS

Abstract

This objective of this study was to determine the impact of antimicrobial carcass washes on beef trim quality in the production of frankfurters. Twenty-four beef carcasses were randomly applied a different antimicrobial wash treatments (TRT) during the harvest procedure: 82° C water (CON), peroxyacetic acid (PAA), or lactic acid (LA). Beef carcasses were analyzed for microbial counts and carcass pH. Frankfurters were produced using carcass trim at two different batter temperature processes (PROC): 4°C (CP) or 21°C (HP). Frankfurters were analyzed for cook loss, emulsion stability (ES), color (Minolta L*, a*, b*) over 60-day storage, purge loss, texture, and sensory analysis. LA carcass had a lower pH (6.36; $P<0.001$) 30 min post wash compared to other wash treatments. Frankfurters produced from CON trim had the highest ES water ($P<0.0001$) and ES fat ($P<0.0001$) separation where the LA and PAA treatments were not significantly different ($P>0.05$). The HP frankfurters had less ES water ($P<0.0001$) and ES fat separation ($P<0.0001$) when compared to CP. However, the CP had a higher cook yield ($P=0.002$). The HP frankfurters had higher internal and external L* values ($P<.0001$; $P<.0001$, respectively). The CP frankfurters had a higher a* (redness) internal color values ($P<.0001$). However, the HP frankfurters had a higher external a* value ($P<.0001$). The HP frankfurters displayed higher internal and external b* (yellowness) values ($P<.0001$). Sensory results displayed the CP frankfurter to have an increase in hardness ($P=0.004$), a decrease in cohesiveness ($P=0.03$) and an increase in juiciness ($P<.0001$). Texture analysis hardness ($P=0.009$) and chewiness ($P=0.01$) results showed the CON frankfurters were significantly

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harder than PAA ($P<0.05$), while LA were not different from CON or PAA frankfurters ($P>0.05$). The CP frankfurters were found to have a decrease in springiness ($P=<.001$) and cohesiveness ($P=0.03$). There was a significant difference in microbial reduction of pre to post wash petri film counts for all treatments ($Log_{10}CFU/mL$) of aerobic plate count ($P= <0.0001$), E.*coli* coliform ($P= 0.0002$), yeast ($P=0.04$) and mold ($P= <0.001$). TRT was found to be significant for APC ($P=0.06$) and yeast ($P=0.004$). Overall, our research indicated antimicrobial wash treatments have little effect on frankfurter quality and displayed viable methods for reducing microbial growth on beef carcasses.

Key words: frankfurter, antimicrobial wash, beef trim, emulsion stability

Introduction

Lean beef trimmings recovered during the fabrication process are utilized in many further processed products, including emulsified products, such as frankfurters. During frankfurter production the goal is to produce a stable meat emulsion by controlling intrinsic and extrinsic factors in order to produce a quality product.

The properties of pH, salt concentration, protein extraction and other non-meat ingredients all affect several sensory factors of frankfurters. When the pH of meat is further away from 5.0-5.2 (isoelectric point of meat 5.0-5.2), there are more protein side chain charges available for water-binding, therefore increasing the water and protein interactions and the functionality of the raw materials for further processing (Maltus et al, 1995, Hamm 1986). However, meat pH can cause negative effect on emulsion stability, as proteins denature at pH values below 5.0, which will cause proteins to become ineffective in forming an emulsion (Hamm, 1986). Salt is necessary in frankfurters as salt-soluble myofibrillar protein distribution properties increase water binding ability and textural properties, which directly affect the gel structure formed during an emulsion, with myofibrillar proteins acting as primary emulsifiers and stabilizers of the meat batter (Lonergan et al, 2013). Therefore, increasing the functionality of the raw materials will produce a more stable meat batter emulsion thus producing a higher quality frankfurter (Gordon et al.,1992).

Frankfurter quality is also dependent on the temperature of processing conditions, chopping time and final batter temperature (Gordon et al., 1992). Temperature increase of a meat batter is important when forming a stable emulsion thus effecting the fat dispersion of the meat emulsion matrix. Increase in temperature causes the fat droplets to decrease in size making the it easier for protein and fat hydrophobic interaction. Jones and Mandigo (1982) studied the effects

of endpoint chopping temperatures of 10,16, 22, 28°C on frankfurters and concluded a higher

cook loss of meat batters greater than 22°C, which was caused by an emulsion breakdown when

chopped at too high of temperatures. Colder chopping temperatures were evaluated by Sutton et

al., (1995) reporting endpoint chopping temperatures at peak of 15°C and below produced the

most stable product in reduced fat high moisture beef frankfurters. However, temperature

differences were found from past research were consistent trim was used and different

antimicrobial wash applications were not tested.

To meet USDA zero-tolerance standards for food borne pathogens, acidic antimicrobial

washes are applied during harvest to decrease microbial load of the beef carcass. Pathogenic

microbes present on the carcass harbored during the harvest process are killed by antimicrobial

washes at low pH (Lahr, 1996). Organic acids such as acetic, citric, and lactic acids are widely

used in the industry as antimicrobial agents (Belk, 2001). Several researchers have found an

immediate decrease in pH of beef trim when antimicrobial washes are applied although after

days of storage the pH equilibrated to show no difference from controls (Ellebracht et al., 2005;

Kang et al., 2001; Anderson & Marshall, 1990; Anderson, et al. 1980). However, antimicrobial

wash applications to beef carcasses have not been evaluated to determine the impact on muscle

pH and possibly emulsion stability as well as frankfurter quality.

We hypothesized carcasses treated with lower pH antimicrobial washes would have an

effect of emulsion stability causing excess water and fat leakage from meat batters, in turn

affecting internal, external and frankfurter sensory attributes. The objective of this study was to

determine the effect of carcass antimicrobial washes and processing temperature variations on

quality attributes of formulated beef frankfurters.

Materials and Methods

Sample Preparation

Over two harvest days (block), twenty-four beef carcasses were selected at the Purdue University Land O' Lakes Center (West Lafayette, IN), twelve carcasses per harvest day. For each harvest day, the carcasses were randomly assigned to an antimicrobial carcass wash treatment (TRT), which included: 82° C water (CON), peroxyacetic acid (PAA) or lactic acid (LA). After evisceration and splitting, a zero-tolerance evaluation for foreign material was observed and carcasses were rinsed with water, and then allowed to drip for 5 min before the carcass wash was applied to both sides of the carcass. The PAA treatment (Crimson Chemical, Fort Worth, TX) initial concentration of 23.72% acid solution was diluted to 350 ppm with water, and 0.5 gallon was applied to each carcass at (55° C). Lactic acid (LA) wash (Corbion, Lenexa, KS) had an initial concentration of 88% lactic acid was diluted to of 5% dilution of the acid solution and one gallon of per carcass at 55°C. The washes were applied using methods proscribed for small processing plants (Cutter et al, 2005). The acid washes were applied using a garden sprayer approximately 30 cm in distance, applying from top to bottom from the carcass at 12-15 psi at 55°C. Carcasses were allowed to drip for 1 to 2 min before entering the cooler 4° C for 24 h. Prewash pH was measured with a pH probe meter (Hanna Instrument, Inc., Warner, NH) in duplicate on the hindquarter (biceps femoris) before carcass wash interventions, as well as 30 min post wash and 24 h post wash.

Microbiology Sampling

Carcasses where aseptically sampled pre and post carcass wash application using sampling sponges with 20 mL buffered peptone water in sterile bags (World Bioproducts,

Bothell, WA). The two moistened peptone sponges were used by swabbing each half of the carcass of the navel, plate, fore shank, and brisket areas pre- evisceration and 30 min post carcass wash. Each half side consisting of 4,000 cm^2 totaling 8,000 cm^2 using (Anderson & Marshall, 1990) procedure. Once the sponges were combined and put on ice until harvest process was completed and kept in refrigeration for 24h until sponges were processed. Adding 10ml of 0.1% buffered peptone into a sterile stomacher bag and stomached for two minutes processed the sponges, serial dilutions were made to 10^{-3}. The dilutions were plated using 1mL of the dilutions were plated on 3M (Maplewood, MN) Aerobic Plate Count (APC), E. *coli*/ Coliform Count (ECC), and Yeast and Mold (Y&M) petri films in duplicate. In all cases, the plate counts were converted to Log$_{10}$ CFU/mL to determine lethality.

Frankfurter Production

Beef trim, 90% lean 10% fat, was collected 24 h post-harvest from the round, chuck and brisket regions. Trim was vacuum-packaged and stored at 4° C for five days to simulate industry processing protocols. Carcass trim from the right side of the carcass were designated for hot (HP) and the left side of the carcass was designated for the cold (CP) frankfurter processing techniques (PROC). Beef trim was pre-ground 12 h before processing using a 3/16th grinder plate. Approximately 14-pound (6.4 kg) batches were produced for each frankfurter processing method. Equipment used throughout the trimming process was cleaned between treatments to prevent cross contamination.

Cold processed frankfurters were made using a Kodiak Varimixer (Varimixer, Charlotte, NC) using the ingredients shown in Table 2.1. A meat pre-blend was made with ground beef mixed with the cure ingredients (6.25% sodium nitrite, A.C. Legg, Inc. Calera, AL) and salt 12 h before frankfurter production for optimum protein extraction. The pre-blend fat and one third of

the initial water (377g) was added to the frankfurter preparation and combined for 30 seconds. Then the spice mix, other non-meat dry ingredients and one third of the water (377g) was added and mixed for 30 seconds. Finally, the last third of the water (377g) was added, and mixed for 30 seconds until meat batter was tacky equaling a final mix time of 1.5 min. The batter was then ground twice using a $3/16^{th}$ grind-plate reaching a final batter temperature of 4° C.

Hot processed frankfurter meat batter was made using lean beef trim ground through a $3/16^{th}$ inch plate meat grinder the 24 hours before the frankfurters were processed. The ground beef trim and cure ingredients (6.25% sodium nitrite) were added to a Stephan vertical chopper (Stephan, Columbus, OH) along with salt and phosphate ingredients on low speed for 1 min. Fat was added and mixed on low speed for 30 s. The remaining dry non-meat ingredients and one third of the water (337g) was included and mixed for ten seconds. The remaining water was added (337g), and the batter continued to mix on high for one min to give a final batter temperature of 21° C. The batter was vacuum-sealed using a Promarks packager (Promarks Inc., Claremont, CA) to release any air from the emulsion. Samples were collected for emulsion stability test and pH analysis. Formulation can be found in Table 2.1.

All meat batters were transferred into a Talsa Stuffer (Talsa, Virivella, EU) and stuffed into a 29-mm cellulose casing. The frankfurters were then linked and weighed before the cook process (Raw Weight). The frankfurters were placed in a Scott Pec smokehouse (ScottPec, Inc Guelph, ON, Canada), cooked to an internal temperature of 71 °C, and cool-showered for 10 min before cook weight was recorded (Cooled Weight). Frankfurters were held at 4° C for approximately 12 h, at which time the casings were removed, and frankfurters were vacuum-packaged. The samples were held at 4° C for instrumental texture, purge, microbiological

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analysis and instrumental color analysis. Frankfurter sensory and extra samples were kept frozen at -40 °C until further analyzed.

Instrumental Color Analysis

Frankfurter internal and external color measurements were taken in triplicate 24 hour post processing using Konica Minolta Cr-400 (Ramsey, NJ) on the C fluorescent illuminator setting to collect the lightness (L*) redness (a*) and yellowness (b*) of the sample for each treatment batch (McGough et al., 2012). For shelf life color analysis, the frankfurters were transferred from –40°C storage into individual bags and placed under a light display for 60 d at 4 °C. Color evaluations were measured by Konica Minolta Cr-400 (Ramsey, NJ, USA) in duplicate at 0 d, 30 d and 60 d.

Emulsion Stability

Emulsion stability (ES) measurements were taken according to Sebrank et al. (2001). Approximately 25 gram of meat batter was injected in a Weirbicki centrifuge tube and weighed. The tubes were cooked in a water bath to 71°C for 30 min, cooled for 5 min and then centrifuged at 750 g_{max} for six min at 25°C. The amount of separated fat and water was recorded in mL in order to calculate the amount of fat and water that was lost during cooking. The calculation used to determine the percent water was:

ES Water Separation %= (mL Water / Fresh Sample Weight) x100

The calculation to determine percent fat are as followed:

ES Fat Separation %= (mL Fat / Fresh Sample Weight) x 100

Instrumental Texture Analysis

The frankfurters were analyzed for texture using the methods of Bourne (1978) and Wenther (2003). Four frankfurter samples stored at 4° C and samples were prepared by cutting into two cores (1.6 cm x1.9 cm) per frankfurter. The cores were analyzed by TA-XT Plus Texture Analyzer (Stable Micro System Ltd.,UK) using a TA-25 cylinder probe to measure hardness, springiness, cohesiveness, adhesiveness and chewiness. Peak compression values were further calculated to determine the overall texture of the frankfurter.

Batter pH

The pH of the meat batter was recorded approximately 6 h post processing following the procedure described by Sebranek et al. (2001). The pH samples were prepared by adding 10 g of batter to 90 mL distilled deionized water and homogenized for 45 seconds, then filtered using Whatman No. 1 filter paper to separate the solution. A bench top pH meter (Satorious AG Gottingen, Germany) was used to measure the pH in duplicate of each batter.

Processing Yield

The processing yield was measured by weighing each batch of frankfurters after stuffing (Raw Weight) and cooled to > 4°C (Cooled Weight). The percentage processing yields were determined by the following equation:

$$\% \text{ Processing yield} = (\text{Cooled Weight} / \text{Raw Weight}) \text{ x } 100$$

Purge Loss

Purge loss of 6 frankfurters was measured approximately 2 weeks post processing. The total weight of the bag with frankfurters (Total Weight), blotted frankfurters weight (Meat

Weight) and dry bag weight (Bag Weight) were all recorded. Total percentage purge loss was calculated used the following equation:

$$\% \, Purge = ((Total \; Weight - Bag \; Weight - Meat \; Weight) \, / \, Meat \; Weight) \; x \; 100$$

Sensory Analysis

Sensory analysis was performed using a trained panel with a minimum of 8 panelists per setting. The panelist performed a 1-hour training session to familiarize themselves of the sensory characteristics using 6 different types of commercially made frankfurters. The frankfurters were analyzed using a 8-point hedonic scale for each sensory attribute of hardness (1=extremely hard, 8=extremely soft), cohesiveness (1=extremely dissolves, 8=extremely cohesive), juiciness (1=extremely dry, 8=extremely juicy), flavor intensity 1=extremely bland, 8=extremely flavorful), and off flavor (1=extremely intense, 8=non detectable).

The frankfurter samples were prepared in a water bath until internal temperature of 71°C was reached. The panelists were given two 1 cm sliced samples for each frankfurter under red lighting in the sensory booths. The panelist cleansed their palate using an unsalted saltine crackers and water between each sample. The panelists were given 6 samples to evaluate with an equal representation of carcass wash treatments (CON, PAA, and LA) and frankfurter processes (CP and HP).

Statistical Analysis

The experimental design was a 3×2 structure in a randomized complete block design of TRT and PROC with carcass side as the experimental unit (n=48). The 3 TRT (CON, LA, PAA) were applied to 12 carcasses and replicated over 2 harvest days (n=24). Each carcass was slit down the medial line, and trim from each side was allocated to the 2 PROC of CP and HP. The

fixed main effects of TRT and PROC and the random effect of harvest day, carcasses and their interactions were analyzed using the mixed procedure SAS software package (9.4, 2012) for ANOVA of microbial analysis, emulsion stability, texture analysis, batter pH, carcass pH, processing yield, purse loss, sensory analysis. The fixed main effects of TRT, PROC, and day, and the random effect of harvest day, and all subsequent interaction were also analyzed using the mixed procedure SAS software for ANOVA of instrumental color. Least square means for all traits were separated by using least significant differences analyzed by the PDIFF option in SAS (9.4, 2012) and considered significant at $P<0.05$.

Results and Discussion

Carcass pH

The results of antimicrobial carcass wash on carcass pH over a 24-hour period of time are displayed in Table 2.2 As expected, there was no significant difference ($P=0.85$) in the prewash carcass pH. At 30 min post wash, LA treatment displayed a lower pH (6.36; $P<0.001$) compared to the CON and PAA treatments (6.74 and 6.96, respectively), which were not different from each other ($P=0.5116$). However, 24h pH results displayed no differences between the antimicrobial treatments ($P=0.51$).

Other studies have found a similar pattern of pH reduction shortly after antimicrobial wash, which then equilibrated after ~24 h. Ellebracht et al., (2005) compared peroxyacetic acid and lactic acid carcass washes and found pH reduced to 3.3 after peroxyacetic acid wash and observed a pH reduction to 3.4-3.7 after lactic acid wash treatments, with both returning to pH of ~5.0 after 24 h of storage. Although our data did not show as drastic of a pH drop, this is likely because these studies evaluated the surface pH, while our investigation evaluated the internal pH of beef hindquarter muscles. Our findings were similar to Kang et al., (2001), which reported

similar pH values of beef trim treated with lactic acid solution where 5.78 and were not significantly changed from the control. Therefore, antimicrobial washes have been found to reduce the surface pH immediately after application, however, our data shows muscle pH is far less impacted by antimicrobial washes, particularly after 24 h, which showed no differences.

Emulsion Stability and Batter pH

Emulsion stability water and fat separations, and batter pH data are shown in Table 2.3 The main effect of carcass TRT had a significant impact in the ES water separation (P=0.05) and ES fat separation (P=0.05), and only slightly approaching significance on batter pH (P=0.13). Frankfurters from CON trim had the lowest ES water separation, while frankfurters from PAA trim had the highest ES water separation, and frankfurters from LA trim were not different from CON or PAA (P=0.51 and P=0.07, respectively). Similarly, frankfurters from CON trim had less ES fat separation than frankfurters from PAA or LA, which were not different from each other (P=0.81). These results could have been caused an effect of pH similar to Hamm (1986) who reported too low pH values can cause protein denaturation, although pH was not significant, these differences could have been caused by a difference in acid wash formulation.

The main effect of PROC had a significant impact on ES water separation (P<0.0001) and ES fat separation (P<0.0001), and approaching significance on batter pH (P=0.09). HP frankfurters had less ES water separation and less ES fat separation indicating greater emulsion stability. This could be expected as it is known that mechanical action must be used to help form an emulsion (Schmidt, 1984) causing the processes at higher temperatures to have greater emulsion stability. Similar results were found in Sutton et al. (1995), who concluded endpoint chopping temperatures of 15°C produced the most stable product in reduced fat high moisture beef frankfurters. Our results vary from other frankfurter work such as Whiting, (1984) which

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found having elevated batter temperatures decrease of gel strength and Lee (1985) who found emulsion stability decreased when higher chopping temperatures were reached. However, these researchers used pork and beef blended trim, resulting in a significantly different fatty acid profile. Beef is higher in saturated fats, meaning the melting point is significantly higher, and will therefore require a higher batter temperature to obtain a stable emulsion. Additionally, similar batter pH results were found in Ambrosiadis et al., (1996) reported initial batter pH values of 6.2-6.3 for meat batters when studying the effects of plant oils in comminuted meat products. Interactions between TRT and PROC were not found for ES water separation (P=0.70), ES fat separations (P=0.15), or batter pH (P=0.25).

Cook Yield and Percent Purge

The cook yield results display no significant difference due to TRT (P=0.64) as shown in Table 2.3. However, there was a significant difference in percent cook yield for PROC (P=0.002) and there was no TRT and PROC interactions (P=0.87). Similar cook yield results were reported of 95-99% cook yield when evaluating phosphate levels of emulsion type sausage (Wang et al., 2009). Additionally, Jones & Mandigo (1982) found comparable cook yield results for temperature ranges of 10°C and 16°C treatments of 93%. In contrast, Jones & Mandigo (1982) reported a much lower cook yield with their 22°C and 28°C treatments, however these were produced with beef and pork blends.

Percent purge results exhibited no significant differences due to PROC (P=0.19), TRT (P=0.3507), or the interaction of PROC and TRT (P=0.37) as shown in Table 2.3. Other studies support this finding of similar results as the cold process may have affected the emulsion stability and cause an increase in purge. Sutton et al., (1995) reported batters processed under 0 °C and 30°C had the largest percent purge of 2.5-2.7% for reduced fat formulated beef

frankfurters respectively similar percent purge loss was found in comparison to this study. Our study displayed no differences in purge comparing the different processing temperatures may be due to the temperature range of the final batter where more favorable for emulsion stability than 0 and 30 °C and did not cause a break down in emulsion because the temperature was too high (Jones and Mandigo, 1982).

Texture Analysis

The texture analysis means comparison can be found in Table 2.4. Hardness values were significantly different between the TRT main effects (P=0.0095). However, no differences where shown in hardness when comparing the PROC (P=0.55) or the TRT and PROC interaction (P=0.98). CON frankfurters were harder than PAA, while LA were not different from CON or PAA frankfurters. Matulis et al., (1995) reported maxium hardness at pH of 6.0 of all treatments with variring salt levels, while our study showed similar batter pH causing those differences in hardness values. Also Matulis et al. (1995) reported hardness decreased as pH increased above 6.3. As shown in Table 2.4, the LA and PAA had higher carcass pH values of the CON treatment. Although carcass pH was only found to be signifanctly different in the 30 minute post wash, pH or other components of the acid wash that could be causing downstream effects on the differences in texture for the treatments. The carcass pH was eqilibrated once the trim was processed therefore little differences were found in batter pH to affect the texture of the frankfurter.

Adhesiveness results exhibited no TRT effects (P=0.99) but there was a difference due to PROC (P=0.03), and the interaction of TRT and PROC was found not significant (P=0.52). CP frankfurters had greater adhesiveness compared to HP frankfurters (P=0.03). Similar differences of adhesiveness were found in the comparison of commercially made low fat frankfurter blends

our frankfurters had the same formulation and fat percentages causing no differences in adhesiveness (Ordóñez et al., 2001).

A significant difference was found in springiness between PROC ($P<0.001$) in turn, there was no difference in TRT effects ($P=0.79$) or the interaction of TRT and PROC ($P=0.54$). HP frankfurters had a higher springiness value as the particle size was much smaller concluding the frankfurter had a firmer gel matrix. Results could have been due to the CP process frankfurters displayed a larger particle size than the hot process frankfurters. Small et al. (1995) observed springiness values to be significantly different when increased particle size and mixing time was analyzed.

Chewiness comparison had similar results to the hardness measurement as it displayed a significant difference in TRT effects ($P=0.01$) but had no significance in PROC ($P=0.08$), and the interaction of TRT and PROC was not significant ($P=0.94$). Similar to hardness, CON frankfurters had the higher chewiness values harder than PAA, while LA were not different from CON or PAA frankfurters. Mittial & Batbut (1994), showed similar differences in a chewiness and reported their differences were obtained by the amount of free or bound water used in the meat matrix for reduced fat frankfurters. Our study found differences in treatments leading one to believe there are some downstream effects of antimicrobial wash pH can on the about of moisture causing the samples to be chewier due to the slight differences in pH can increase the water binding ability of an emulsion.

Finally, cohesion analysis displayed no difference in TRT ($P=0.25$) or PROC ($P=0.51$) and the interaction of TRT and PROC was ($P=0.69$). This is similar to findings of Hensley & Hand, (1995) who reported no change in cohesion for batters produced at different chopping temperatures of 9, 12 or 15°C.

Gumminess analysis displayed no differences in PROC (P=0.94), TRT (P=0.14), or the interaction of TRT and PROC (P=0.53). In contrast, Barbut and Mittal (1990) found differences in chewiness for meat batters produced with increasing temperatures to 50, 60 and 70° C. This may be because we did not process our raw batter to that high of a temperature. Also, the antimicrobial wash showed no effects on some texture analysis attributes. These results could have been caused from the wash only penetrating the surface of the carcass.

Sensory

Sensory traits were analyzed with a trained panelist on an 8-point hedonic scale results can be found in Table 2.5. Hardness (P=0.004), cohesiveness (P=0.03), and juiciness (P<0.0001) values displayed a significant difference due to the main effect of PROC however; no significant difference was found due to TRT or the interaction of PROC and TRT (P>0.05). The CP frankfurters appearance to have larger lean and fat particle sizes when compared to the HP frankfurters. The panelist's scores reflected the CP frankfurter sensory attributes to be softer, less cohesive, juicier and had a slightly higher overall acceptability rating than the HP frankfurters. Also, Matulis et al.,(1995) observed softer frankfurters with a reduction of protein- protein interactions of a meat matrix. The cold process frankfurters could have experienced less protein extraction due to the different mechanical action used causing the softer texture frankfurter. Moreover, Lee et al., (1987) observed chopping time directly affects hardness and panelist desirability for frankfurters. Shorter chopping time results in larger fat globules (Barbut, 1990). Although the frankfurters in the study were chopped at similar time parameters, different mechanical action was used for the PROC groups causing the CP groups to have a more desirable texture, juiciness and hardness scoring. The main effects of PROC and TRT had no

effect on flavor intensity (*P*=0.25) and the interaction of PROC and TRT was not significant (*P*=0.71).

Color

Frankfurter internal and external color results were obtained for L*, a*, and b* values and can be found in Figure 2.1- 2.6 respectively over a 60-d time period. The main effect of PROC displayed significance of internal and external values for L* (*P*=<0.0001; *P*=<0.0001, respectively), a* (*P*=0.010; *P*=0.001, respectively), and b* (*P*=<0.0001; *P*=<0.0001, respectively) over the 60-d time period, however, there was no significant PROC by day interaction (*P*>0.05). Figure 2.2 shows HP had higher L* values for both internal and external color that was consistent across all days indicating a greater lightness in HP frankfurters. The a* values were higher (redder) for the CP frankfurters internally, however externally, the HP frankfurters were higher at all days (Figure 2.4). Figure 2.6 shows the b* values as higher for the HP frankfurters both internally and externally at all days indicating a greater yellowness in HP frankfurters. Comparative results were found by Small et al. (1995) as particle size increased b* values were significantly different when studying the effects of particle size and sensory characteristics of low fat high moisture pork frankfurters.

The main effect of TRT had no effect on internal and external for L*, a*, and b* color values over time L* (*P*=0.52; *P*=0.75, respectively), a* (*P*=0.28; *P*=0.42, respectively), and b* (*P*=0.979; *P*=0.83, respectively) and there was no interaction of TRT and day (*P*>0.05). There is little research about antimicrobial washes affecting the color of processed meat products. However antimicrobial ingredient compounds have been added to frankfurter type sausage and have shown natural extracts of green teas, stinging nettle and olive leaves showed the L* and a* values decreased after 45 days of storage (Alirezalu et al, 2017). Also additions of sodium lactate

beef bologna type sausage reported an increase in fade appearance and at 6 weeks of display (Brewer et al.,1992).

Microbiology

Microbiological sponge testing was performed on the carcasses to insure lethality of present microbes on beef carcasses and the results of the least square means comparison of logarithmic reduction (Log10 CFU/mL) can be found in Figure 2.7. ECC film counts displayed a significant difference between pre and post WASH (Figure 2.7; P= 0.0002), however there was not a difference in TRT (Figure 2.7; P=0.89). APC film count results showed a significant difference between pre and post wash (Figure 2.7; P= <0.0001) and significant difference in TRT (Figure 2.7; P= 0.006) and a TRT and WASH interaction occurred (P=0.002). Yeast counts show that TRT (P= 0.04) and WASH (P= 0.004) were significantly different in comparison and no interactions were found. Mold counts were found to have a significant decrease in pre and post WASH (Figure 2.7; P= <0.001), however TRT had no effect on the mold counts (Figure 2.7; P= 0.59) and no TRT and WASH interactions occurred. Similar research has been found 2% lactic acid solution to be the most effective microbial wash treatment when compared to other treatments (Ransom et al., 2003). Ellebracht et al., (2005) reported 2% lactic acid was found to be more effective in reducing pathogens on beef trim than peroxyacetic acid. Additionally, Barkate et al., (1993) found 82°C hot water to be an effective antimicrobial wash application for beef carcasses. The studies previously mentioned were used inoculated carcasses with pathogenic bacteria. However, our research was more focused on the decontamination for everyday commercial use or small meat processors, which could be the reason we found some difference between the treatments due to not inoculating the carcasses.

Conclusions

Overall these data suggest that antimicrobial wash treatments are still an effective way to control microbial growth for beef carcasses. However, there was not as much effect on muscle pH as originally hypothesized as the carcass pH equilibrated after 24 hours. A significant difference in raw emulsion stability was found however post cook/smoke process had little effect on frankfurter color, purge, cook yield, texture, and sensory analysis of the finished product and may be of less concern to the industry. Also, different processing temperatures showed a greater effect on product appearance and color, texture, and sensory analysis providing more consumer insight of the final product in relation to a courser ground frankfurter product.

Moving forward more research can be done to identify how much the acid wash penetrates the muscle tissue of the carcass or pretreated trim to observe the effects of raw meat functionality for the use of further processed products. Additionally, more investigation on antimicrobial washes or increased concentration could affect ingredient functionality of other processed products such as luncheon meats using different species and varying fat blends.

Table 2.1 Hot and cold beef frankfurter formulation for different process conditions

Hot Process (HP)		Cold Process (CP)			
Final Blend		Pre-Blend		Final Blend	
Ingredient	Percent	Ingredient	Percent	Ingredient	Percent
Beef 90's Trim	53.16	Beef 90's Trim	53.16	Pre-blend	57.94
Beef Fat	17.72	--	--	Beef Fat	17.72
Water	17.81	Water	2.13	Water	15.69
Salt	2.03	Salt	2.03	--	--
Nitrite (6.25%)	0.18	Nitrite (6.25%)	0.18	--	--
Corn Syrup Solids	2.96	--	--	Corn Syrup Solids	2.96
Food Starch	1.48	--	--	Food Starch	1.48
Dextrose	0.99	--	--	Dextrose	0.99
Vinegar	1.48	--	--	Vinegar	1.48
Spice Blend	1.72	--	--	Spice Blend	1.72
Sodium Phosphate	0.44	Sodium Phosphate	0.44	--	--
Sodium Erythorbate	0.04	--	--	Sodium Erythorbate	0.04

Table 2.2: Effect of carcass antimicrobial washes (82° C water, CON; lactic acid, LA; peroxyacetic acid PAA) on muscle pH of beef hindquarter (prior to antimicrobial wash, Prewash pH; 30 min after antimicrobial wash application, 30 min Post Wash, and 24 h Post Wash and 24 hours after antimicrobial wash application, 24 h Post Wash).

	Treatment			SEM[1]	P-value
	CON	LA	PAA		
Prewash pH	6.9	6.9	6.9	0.11	0.85
30 min Post Wash pH	6.7[a]	6.4[b]	6.9[ab]	0.10	<0.001
24 h Post Wash pH	5.7	5.8	5.8	0.05	0.51

[1]Standard error of the mean

[ab]Means with differing letters, are significantly different P<0.05

Table 2.3: Effect of carcass antimicrobial treatment (82° C water, CON; lactic acid, LA; peroxyacetic acid PAA) and processing techniques (final batter temperature 4ºC, CP; final batter temperature 21ºC, HP) on emulsion stability measurements, batter pH, processing yield, and purge loss of frankfurters.

	Treatment					Processing			
	CON	LA	PAA	SEM[5]	*P*-value	CP	HP	SEM[5]	*P*-value
ES Water Separation (%)[1]	2.3[b]	2.9[a]	2.5[ab]	0.14	0.05	3.3[a]	1.8[b]	0.20	<0.0001
ES Fat Separation (%)[2]	0.6[b]	0.9[a]	0.9[a]	0.11	0.05	1.3[a]	0.3[b]	0.09	<0.0001
Batter pH	6.3	6.2	6.2	0.07	0.13	6.2	6.3	0.06	0.09
Cook Yield (%)[3]	93.8	93.5	93.9	1.53	0.64	94.4[a]	93.1[b]	1.52	0.002
Purge (%)[4]	1.3	1.7	2.4	0.52	0.35	2.2	1.4	0.42	0.19

[1]Emulsion Stability Water Separation= (mL water / fresh sample weight) x100

[2] Emulsion Stability Fat Separation= (mL fat / fresh sample weight) x 100

[3]Processing Yield = (Cooled Weight / Raw Weight) x 100

[4]Purge = ((Total Weight – Bag Weight – Meat Weight) / Meat Weight) x 100

[5]Standard error of the mean

[ab]Means with differing letters, are significantly different *P*<0.05

Table 2.4: Effect of carcass antimicrobial treatment (82° C water, CON; lactic acid, LA; peroxyacetic acid PAA) and processing techniques (final batter temperature 4°C, CP; final batter temperature 21°C, HP) on texture analysis of frankfurters

	Treatment					Processing			
	CON	LA	PAA	SEM[1]	*P*-value	CP	HP	SEM[1]	*P*-value
Hardness (g)	12188[a]	10639[b]	11639[ab]	341.4	0.0096	11369	11608	278.7	0.55
Adhesiveness (g. sec)	-15.7	-15.2	-15.3	2.16	0.98	-18.3[a]	-12.5[b]	1.8	0.03
Cohesion	33.7	34.4	34.8	0.44	0.24	34.48	34.13	0.4	0.51
Springiness (%)	0.7	0.7	0.7	0.01	0.79	0.64[a]	0.67[b]	0.004	<0.001
Gumminess	88.9	88.8	89.9	0.40	0.15	89.19	89.21	0.3	0.94
Chewiness	7972.0[a]	7001.7[b]	7578.6[ab]	218.1	0.01	7282.6	7578.6	178.2	0.07

[1]Standard error of the mean
[ab]Means with differing letters, are significantly different *P*<0.05

Table 2.5: Effect of carcass antimicrobial treatment (82° C water, CON; lactic acid, LA; peroxyacetic acid, PAA) and processing techniques (final batter temperature 4ºC, CP; final batter temperature 21ºC, HP) on sensory analysis of frankfurters.

	Treatment					Processing			
	CON	LA	PAA	SEM[6]	*P*-value	CP	HP	SEM[6]	*P*-value
Hardness[1]	4.5	4.6	4.6	0.15	0.72	4.8[a]	4.3[b]	0.12	0.004
Cohesive[2]	4.9	4.7	4.7	0.12	0.68	4.6[a]	4.9[b]	0.10	0.03
Juiciness[3]	4.8	5.0	4.8	0.10	0.31	5.3[a]	4.5[b]	0.09	<0.001
Flavor Intensity[4]	5.6	5.6	5.4	0.08	0.25	5.6	5.5	0.07	0.60
Off Flavor[5]	7.3	7.2	7.3	0.08	0.73	7.2	7.4	0.07	0.06

[1]Hardness: 1=extremely hard, 8=extremely soft
[2]Cohesiveness: 1=extremely dissolves, 8=extremely cohesive
[3]Juiciness: 1=extremely dry, 8=extremely juicy
[4]Flavor intensity: 1=extremely bland, 8=extremely flavorful
[5]Off flavor: 1=extremely intense, 8=non detectable
[6]Standard error of the mean
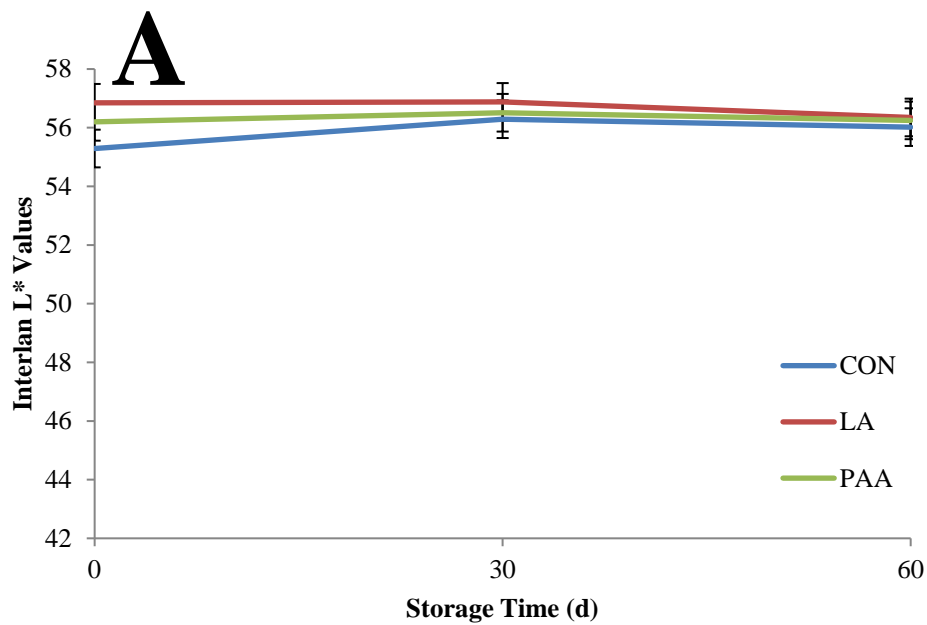[ab]Means with differing letters, are significantly different *P*<0.05
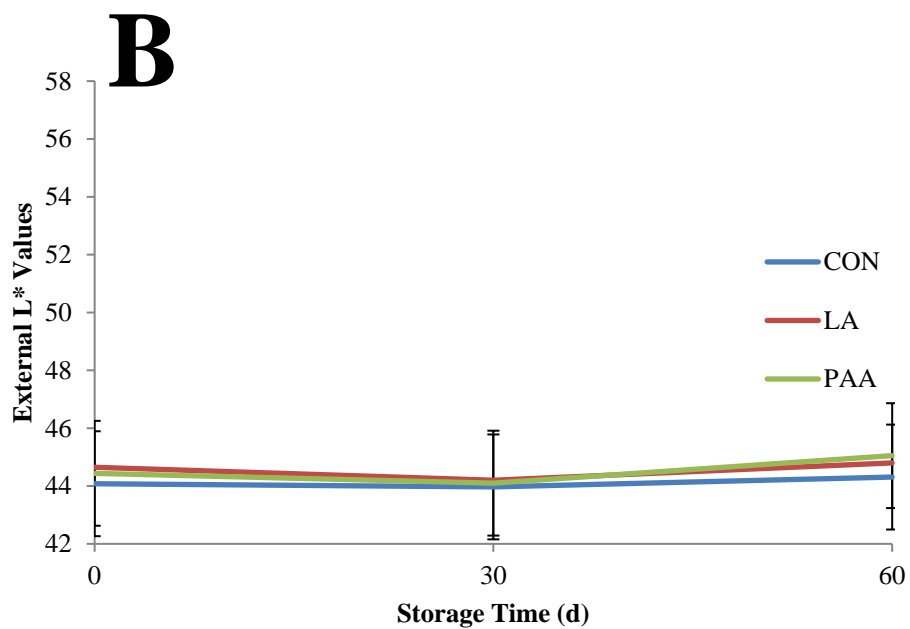
Figure 2.1: Minolta L* values of internal (A) and external (B) measurements of frankfurters processed from trim of different antimicrobial carcass treatments (82° C water, CON; lactic acid, LA; peroxyacetic acid PAA).
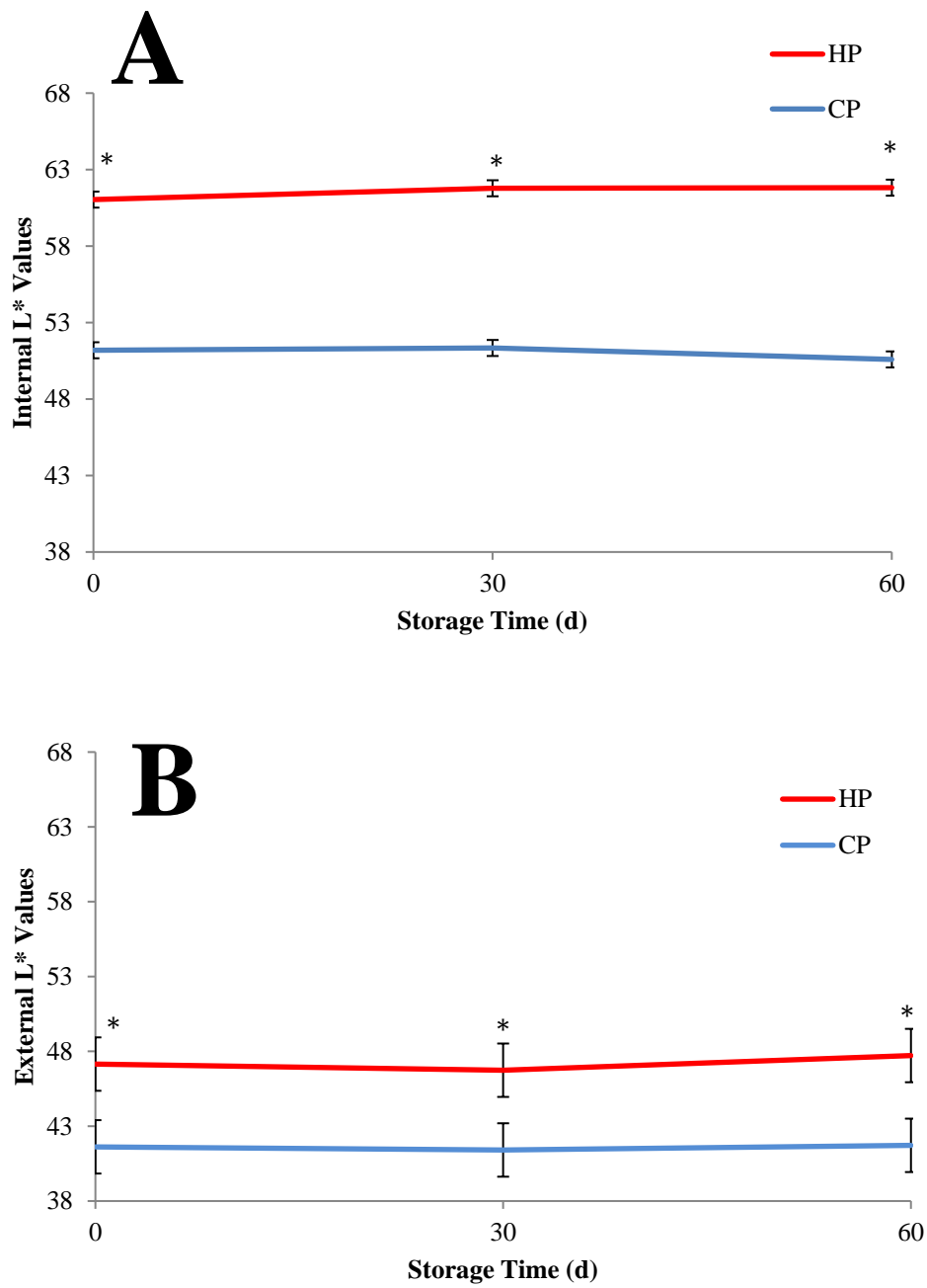
Figure 2.2: Minolta L* values of internal (A) and external (B) measurements of frankfurters from different processing techniques (final batter temperature 4ºC, CP; final batter temperature 21ºC, HP). *P<0.05
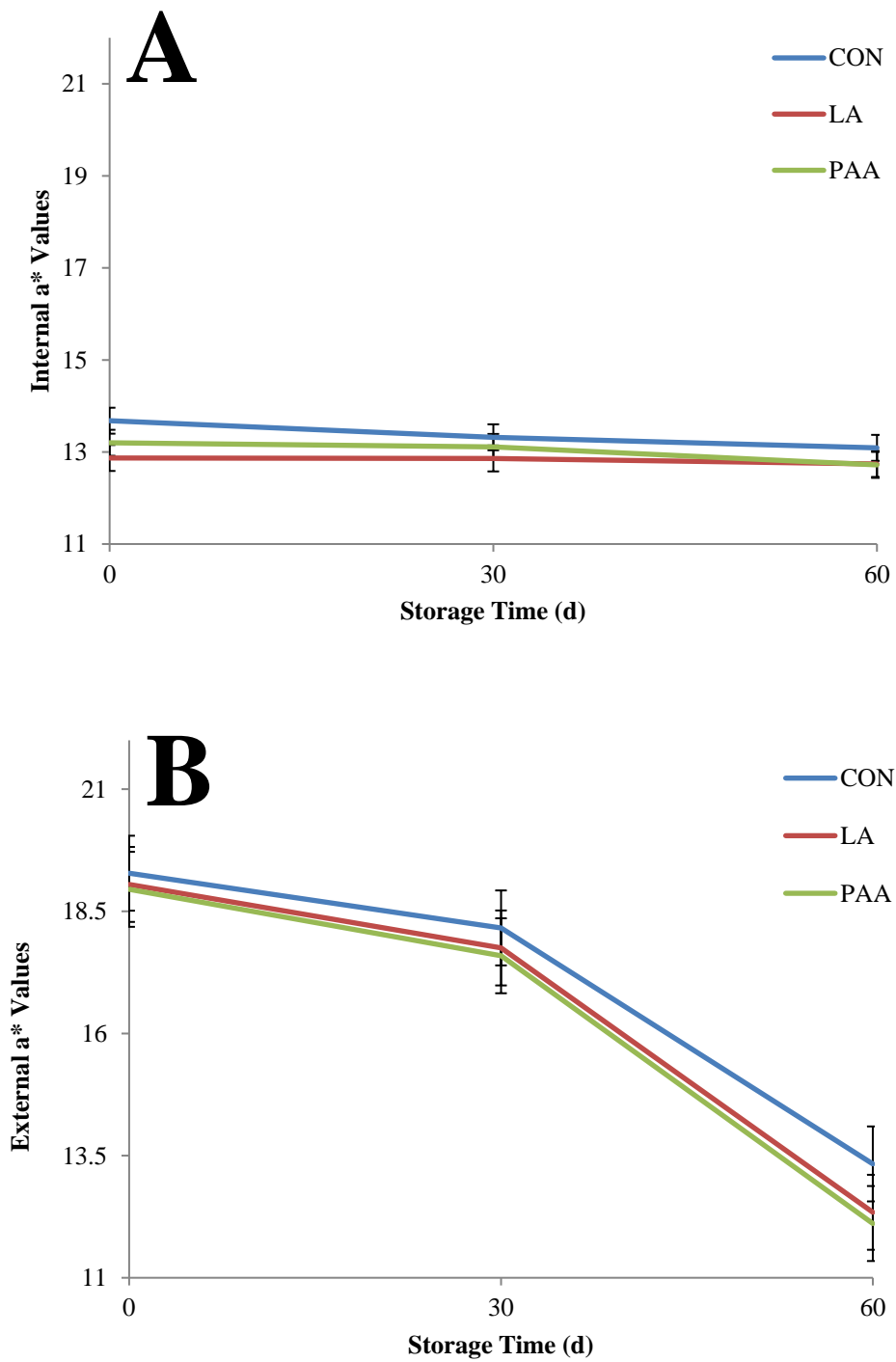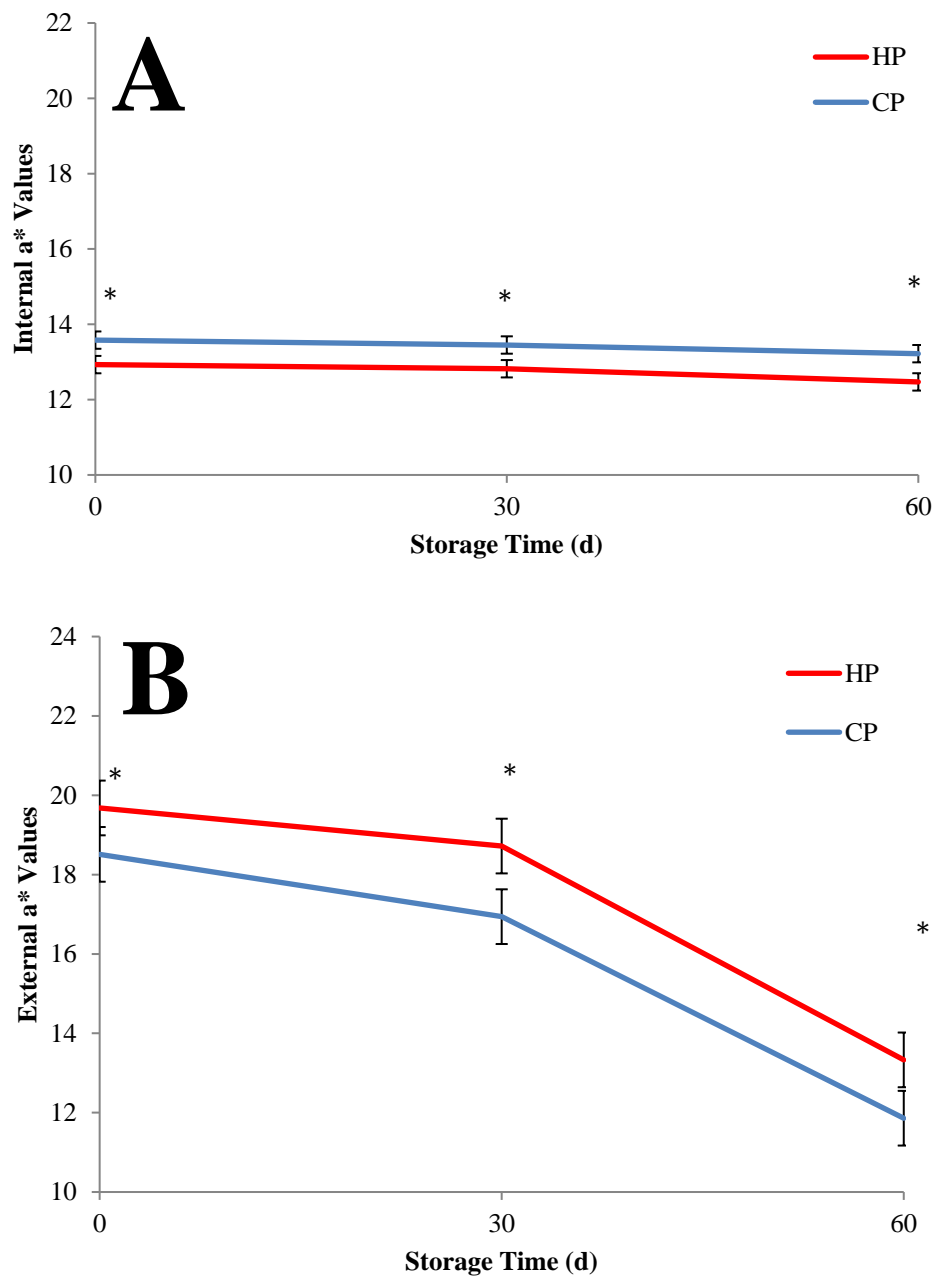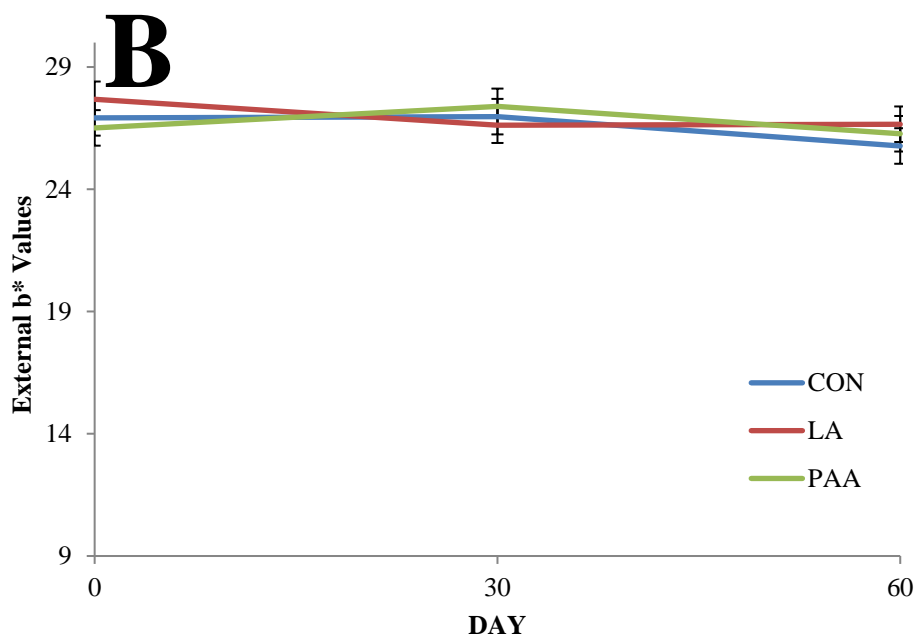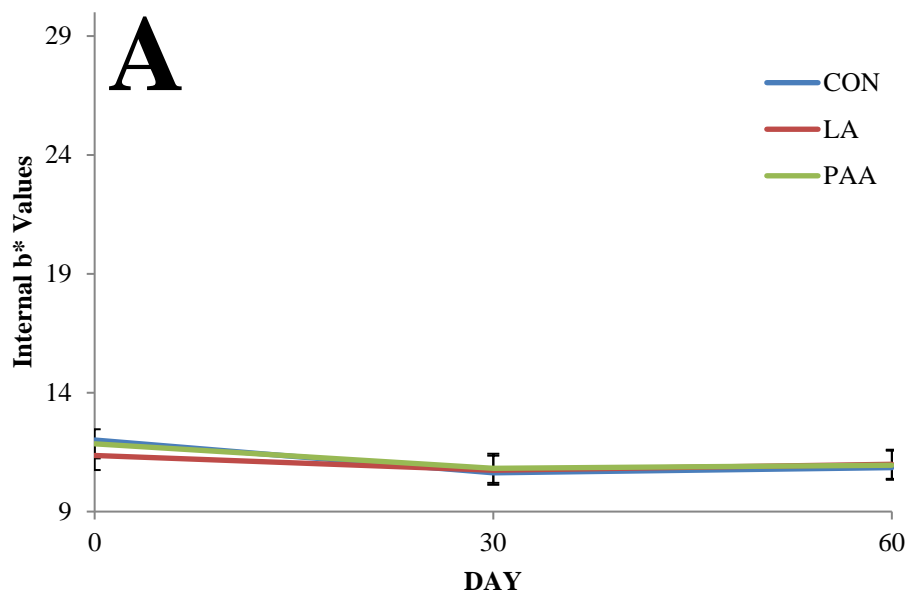
Figure 2.3: Minolta a* values of internal (A) and external (B) measurements of frankfurters processed from trim of different antimicrobial carcass treatments (82° C water, CON; lactic acid, LA; peroxyacetic acid PAA).

Figure 2.4: Minolta a* values of internal (A) and external (B) measurements of frankfurters from different processing techniques (final batter temperature 4°C, CP; final batter temperature 21°C, HP). *P<0.05

Figure 2.5: Minolta b* values of internal (A) and external (B) measurements of frankfurters processed from trim of different antimicrobial carcass treatments (82° C water, CON; lactic acid, LA; peroxyacetic acid PAA).
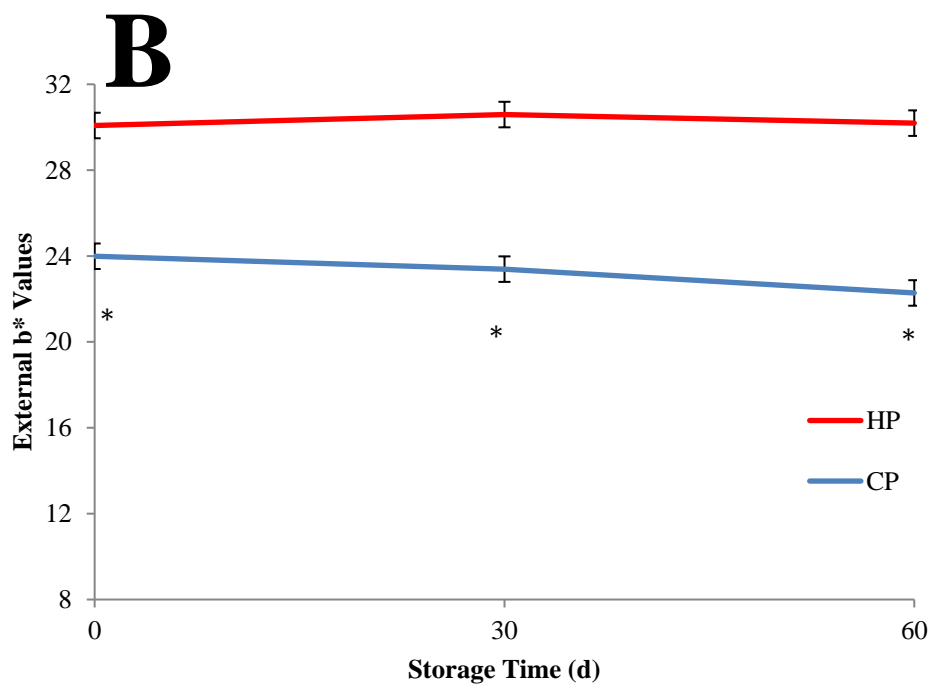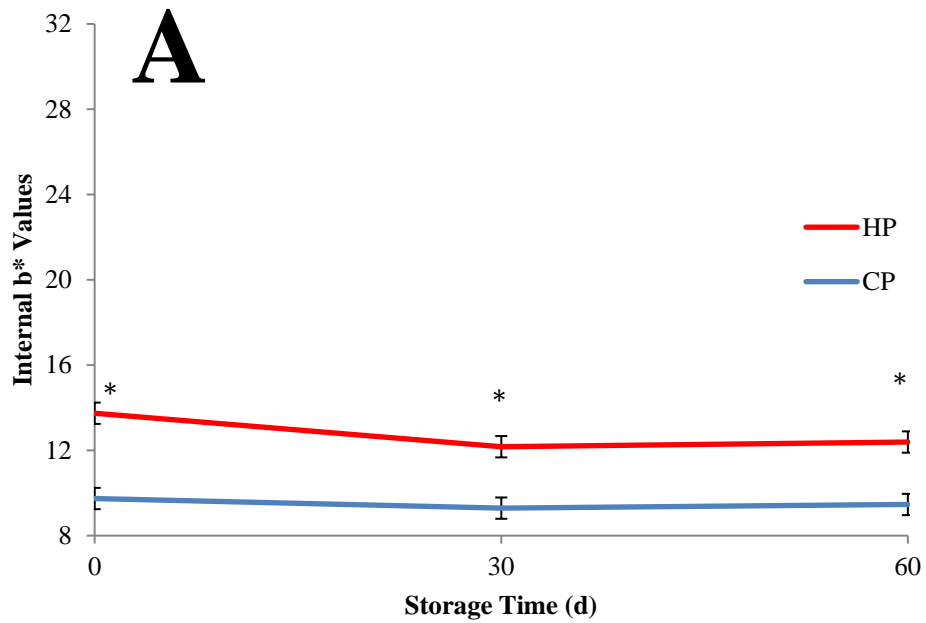
Figure 2.6: Minolta L* values of internal (A) and external (B) measurements of frankfurters from different processing techniques (final batter temperature 4°C, CP; final batter temperature 21°C, HP). *P<0.05

Figure 2.7: Logarithmic (log10) reductions of E. *coli* Coliforms(ECC) Aerobic plate count (APC) Yeast and Mold count for pre and post carcass wash comparison of Control (CON), Lactic Acid (LA), and Peroxyacetic Acid (PAA) and sampled microbial presence and lethality from round and chuck regions of a beef carcass totaling 8,000cm^2
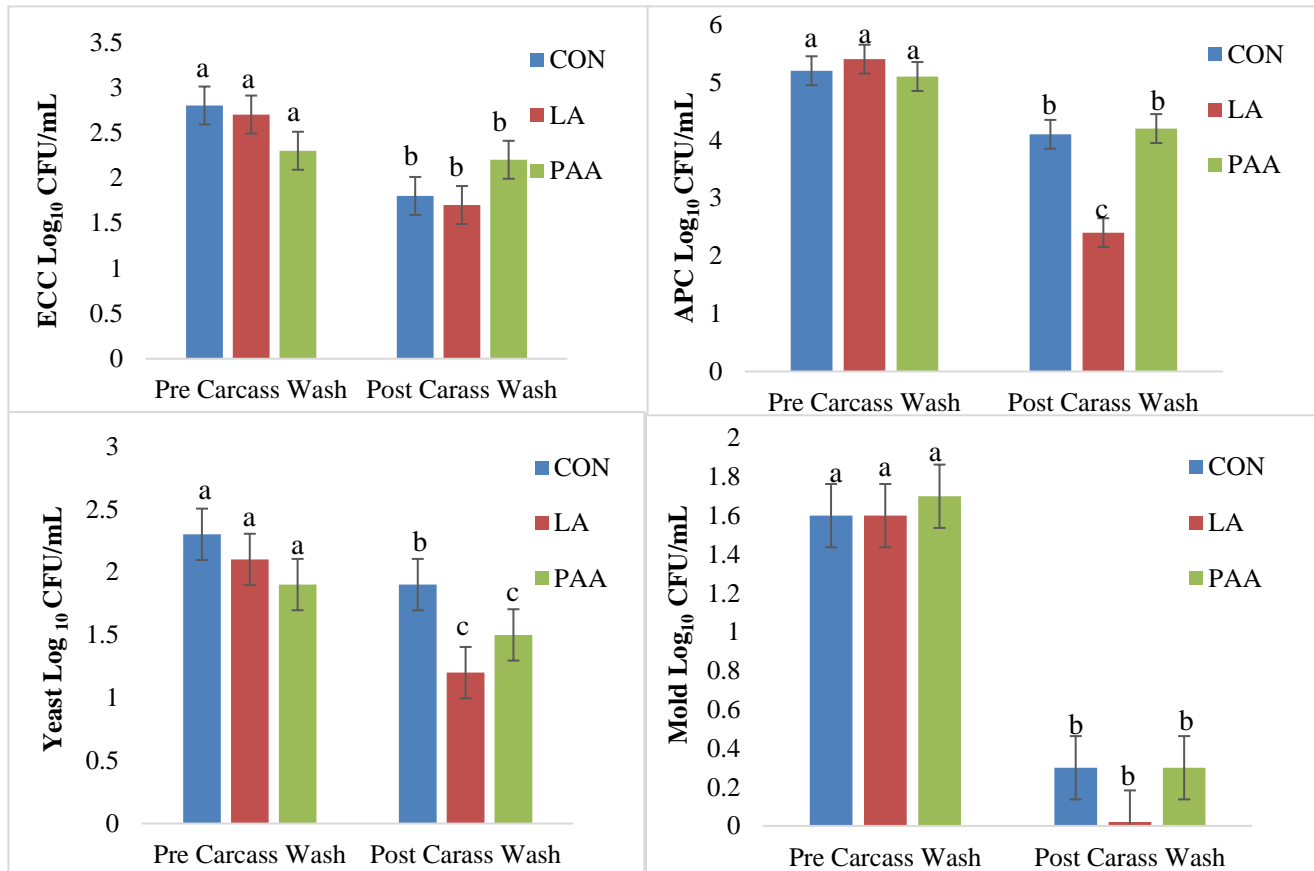
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