THE POULTRY FOOD SYSTEM: A FARM TO TABLE MODEL

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Statement of the Issues and Justification:

The world poultry industry has maintained growth at unprecedented rates while consumer life styles and food preferences continue to change. Convenience foods that are consumer-friendly, affordable, nutritious, safe, and able to satisfy all of the basic consumer's quality preferences continue to direct the poultry industry's marketing path. To meet these needs, poultry producers and processors with the aid of University-directed research such as through the efforts of regional research projects are seeking to develop advanced production and processing technologies for use in producing consumer-oriented products. These changing technologies will require new basic knowledge about regional poultry production and processing efficiencies, and the safety, functional properties, and stability of poultry and egg products. In addition to the efforts of the poultry industry, much of the fundamental research that supports these efforts can best be achieved by coordinating and directing the efforts and expertise of individual researchers within experiment stations into regional efforts that prevent duplication and take advantage of unique capabilities of individuals and facilities at different locations. This regional project is composed of three objective areas: 1. Poultry Meat Safety, 2. Poultry Meat Quality, 3. Egg Quality and Safety. The intent of this multistate regional research project is to efficiently use the capabilities of the cooperators and their respective facilities to achieve the project objectives that address current regional and national priorities of improving consumer food safety and product acceptance, and the commercial profitability of poultry meat and eggs by solving critical problems related to the quality of poultry meat and eggs; specifically color, flavor, or texture of the product, and the safety of poultry meat and eggs; specifically pathogen colonization, contamination, decontamination.

Poultry Meat Safety

Outbreaks of foodborne illness continue to persist in the U.S. food supply even though it is considered one of the safest in the world. There are an estimated 60 to 80 million individuals who contract foodborne illness each year leading to approximately 3~~5~~,000 deaths (CDC, 2012). The annual costs of foodborne illness in the U.S. are estimated at from $5 to $6 billion, including both medical costs and productivity losses. Poultry products have come under scrutiny over the past several years due to listeriosis outbreaks and product recalls of precooked ready-to-eat products. As a consequence, the FSIS has implemented a zero tolerance for *Listeria monocytogenes* in ready-to-eat products. Although FSIS instituted HACCP in 1996, food-borne illness continues to be a significant problem in consumers of poultry. Poultry processing plants throughout the U.S. are challenged by even lower USDA ~~having difficulty consistently achieving the~~ *Salmonella* standards~~Performance Standard~~. Thus, the need to develop intervention strategies to aid in the elimination of pathogenic bacteria from the nation' s food supply is a concern for both producers and consumers of poultry products. Moreover, USDA-

FSIS has recently enacted *Campylobacter* standards. Many poultry companies are having difficulty meeting these standards as no field interventions exist for this pathogen.

Removal and destruction of pathogens on the surfaces of poultry products are important links in the goal of producing pathogen-free products. Hence, new methods to reduce bacterial populations inherent to poultry products are needed while assuring that products reach the consumer in a wholesome state. Previous studies (NC, SC) have successfully demonstrated that the combination of in-package surface pasteurization and primary packaging films that deliver food-grade bacteriocins to the surfaces of fresh poultry products eliminates pathogens on meat surfaces.

The failure to identify effective intervention strategies such as proposed in this project would not reduce the present risk of foodborne illness associated with the consumption of contaminated poultry products and would lead to a significant economic loss for both industry and consumers. Moreover, the significant cost of product recalls of ready-to-eat poultry products stemming from *Listeria monocytogenes* contamination would continue to further threaten the economic vitality of the commercial poultry industry.

The participating scientists have previously conducted and published the findings from several studies that have successfully demonstrated the feasibility of inhibitory biocides and in-package heat treatments acting alone to reduce food pathogen populations on the surfaces of meat products. The advantages of conducting this study under a multistate arrangement are the utilization of expertise that exists at separate institutions. Dr. Dawson (SC) brings to the project the necessary expertise and production facilities required to develop and test the biocide-containing packaging films used in the in-package pasteurization process. SC is known for outstanding food research packaging program and facilities. Without the collective expertise of these two investigators and their accessible facilities, the satisfactory completion of this project would not be possible. Dr. Alvarado (TX) and Dr. McKee (AL) have expertise in the use of antimicrobial ingredient addition into meat products to inhibit microbial growth, especially in ready to eat products. Because of the level of sophistication required to conduct pathogen intervention research, a multistate effort is required. For example, to conduct a study to determine the effect of multiple interventions on *Listeria* contamination of chicken breast fillets and the effect of these interventions on meat quality, a pilot scale facility would be needed to apply chemicals during processing (AL, AR, GA), a cooking facility to fully cook the products (AL, TX), and a packaging facility to package the products (SC).. No such single research facility exists at one institution that can meet all of these needs.

Exclusion of pathogens and spoilage microorganisms from ready-to-eat poultry products by a simple non-evasive process, such as described in this study, achieved in a practical and economical way such as an in-package process, could contribute to a significant decrease in the incidence of human illness and the attendant costs. The combination of in-package pasteurization with preservatives could also assure the safety and quality of poultry products throughout retail marketing. Other project impacts would include documenting and validating the conditions required to produce a safe ready-to-eat poultry product. Moreover, evaluating inhibitory agents with thermal treatments coupled with existing modified atmosphere packaging technology for use in reducing pathogens on poultry products will be useful for gaining acceptance of these processes by regulatory agencies. By teaming with commercial film producers (Cryovac or Sealed Air Corp.) the methodology generated in our proposed study can be used to develop commercially valid processes that will ensure product safety while maintaining product quality.

Poultry Meat Quality

Total U.S. per capita consumption of poultry meat has doubled in the past ~~30~~ 40 years alone, increasing from 48 lbs in 1970 to nearly -100~~10~~ lbs in 2010~~03~~ with the majority (>60%) comprised of boneless meat. Today, approximately 90% of the market consists of parts and further processed products compared to only 20% in 1960. The demand for boneless breast meat has steadily increased over the past 30 years and is produced for many market segments including retail, foodservice, and further processing. Broilers are processed in a variety of weight ranges in order to meet specific customer needs, and the processing of large birds, 6-9 lb., is becoming increasingly popular. More recently, a greater percentage of boneless, skinless breast meat comes from the big bird market segment because of increased yields and pounds per man hour. The average live weight of birds in this segment is now around 7.6 lbs. (ranging 6-9 lbs), approximately a 15% increase over 10 years ago. This demand has been met in part by the poultry industry's aim to provide lean and convenient products and to focus on the further processed markets. Concerns about maintaining quality, color, flavor, and functionality of poultry products are continuing to be expressed by both the poultry processing industry and consumers, especially as growth rate and bird sizes (weights) have increased. Furthermore, consumer expectations for consistent quality are increasing while demands for convenience have resulted in processes, such as accelerated processing and precooking, that place severe strain on color, textural, and flavor because of incomplete resolution of rigor mortis and the tendency for poultry meat lipids to oxidize resulting in "warmed over flavors". Continuing prevalence of defective meat such as PSE and white striping conditions and failure to reduce the incidence and/or severity of those conditions will further reduce the efficiency and competitiveness of the U.S. poultry industry in the global poultry market.

Current and future trends include the use of marination for the enhancement of meat quality, controlled atmosphere and low atmosphere stunning, chilling processes, streamlined processing (minimal aging), portioning and packaging techniques. These trends have the potential to impact poultry meat quality positively or negatively. Currently in the U.S. food industry, there is a trend toward marinating poultry products as a way to add value to the product and/or to improve quality of early deboned meat or PSE-like meat. Popular and functional non-meat ingredients including soy protein, carrageenan, and modified food starch have been traditionally added to meat products to serve as extenders, binders, and fillers in emulsified and comminuted products. However, there is limited information on the ability of these non-meat ingredients to increase the water holding capacity of whole muscle products. Because these products are used to increase the water holding capacity in many blended food products, they may be effective in improving poultry deli loaves made with whole muscle poultry meat that exhibit the PSE condition. If these ingredients can restore meat functionality, then yield losses currently incurred would dramatically diminish resulting in economic benefits to the industry. However, clean labels (limited ingredients, recognizable by consumers) are also in demand by consumers and therefore, processors. Using limited ingredients can result in continuted poor meat qualiy characteristics in finished products if raw ingredients are of poor quality (i.e,. PSE meat).

Animal welfare is a major concern in animal agriculture. Stunning methods for poultry are important as they are tools to render birds unconscious prior to slaughter. Developing and/or optimizing stunning methods are areas for research addressing both welfare and quality issues. Controlled atmosphere and low atmosphere stunning methods are less common in the U.S, but are effective means for humanely rendering birds unconscious. However, some of these methods are new or have new delivery technologies and therefore, have limited information available on its impact on quality. Furthermore, pressures from consumer groups may impact the use of such technologies in the future so research in this are should be kept on the forefront.
In the last decade, the poultry industry has been challenged with the problem of PSE-like turkey meat, similar to the condition found in pork. PSE meat is unacceptably *pale* in color, forms *soft* gels, and is *exudative*. It has been estimated that up to 50% of today's poultry meat has a lightness value sufficient to be classified as pale. It is estimated that a single processing plant could be losing $2 to $4 million per year due to lost yield (drip and cook losses). In addition, poultry processors are concerned with the appearance of this PSE meat in fresh tray packs as the excessively pale color can affect color uniformity within the package and consumer appeal. A more recent quality defect for broiler breast meat is the appearance of white stripes in the meat. Research shows that consumer acceptance of the appearance of these fillets is significantly affected which could result in decreased sales at the retail level. The condition is related to rapid growth rate and while initial results have indicated that some meat quality parameters are not affected, the overall effect on product quality is not known. Furthermore, the relationship between animal welfare and this condition is not known.

There are multiple production and processing factors that negatively impact the quality of the product. The ability of an individual investigator to fully address each of the factors associated is remote because of time, resource, and expertise limitations. However, collectively through a regional research partnership, the scientific expertise and infrastructure exists to address the external components that influence the four critical research problems. Thus, the probability of identifying solutions to these problems is enhanced considerably through regional research collaborations as opposed to the isolated efforts of individual investigators. The farm-to-table approach will be applied to solving problems associated with the biology of poultry meat and its response to the processing and retail environments. This multi-institutional and multi-dimensional effort will involve research on the slaughter plant and the fabrication/retail environments to achieve solutions for maintaining tender poultry meat during changes in processing schemes, the reduction or better utilization of the defective meat, and maintaining high quality meat or improving meat quality of meat processed using technologies new to the U.S. poultry industry. Within each of these dimensions, the focus of the studies will be on identification of causative factors for each meat defect in an effort to reduce its incidence, further characterization of the defective meat, or corrective factors/techniques that may improve the use of the defective meat. Studies will focus on developing new technology methods to improve meat tenderness of early harvested breast fillets; these methods must be able to easily fit into processing schemes.

The inconsistent occurrence of PSE meat in test or commercial flocks combined with the lack of knowledge about its causes as well as the white striping issue in meat makes the interdependence of stations essential for solving this problem. There will be considerable exchange of birds, meat, and information between stations in the proposed studies. This exchange is required because some stations do not have ready access to live production or processing facilities. Sharing information and materials will provide a more efficient use of resources and provide a more organized and comprehensive approach to solving this problem. The impact of successfully completing this project will aid in the reduction of the incidence of PSE-like meat in poultry and the reduction in lost yield. It could also aid in reducing the incidence and/or severity of white striping in meat which may help to improve consumer acceptability of fresh retail products. Benefits of understanding the causes of both conditions may also lead to better animal welfare.

Stakeholders (researchers and industry personnel) need a clearer description to understand the requirements for “true” kosher and halal slaughter as it applies to the slaughter and bleeding of poultry and its relationship to other commercial bleeding procedures. Unfortunately, most descriptions of kosher and halal slaughter methods are superficially reported and the reader is left to assume what procedures were done. Presently, inappropriate references to “kosher” or “halal” slaughter methods are common in the published literature. This misrepresentation will continue until clearer anatomical and religious requirements are described, published, and widely distributed. The absence of clear definitions perpetuates the confusion and inaccurate conceptions related to the bleeding methodology required for religious slaughter. The collaborating scientists have first hand knowledge of ritual kosher and halal slaughter, expertise in avian anatomy, and have demonstrated the ability to prepare informational brochures, manuscripts, and lecture material. Kosher processing plants in the states of New Jersey, Iowa and Pennsylvania, have working relationships with Dr. Regenstein (NY) who has in-depth knowledge of kosher (Jewish) slaughter. Dr. Buhr (ARS) has a background in anatomy and cooperates with commercial broiler processing plants in the Southeast. Providing precise descriptions of the slaughter and bleeding methods will enable a clearer interpretation of published research and a better understanding of the physiology and mechanics of slaughter and bleeding. NY, ARS will work with other stations the impact of religious slaughter on food safety and meat quality.

<u>Egg Quality and Safety</u>

Eggs are a significant agricultural commodity and an important portion of America’s diet. Americans consumed approximately 248 eggs per capita annually, fueling a domestic egg industry that produced 78.5 billion eggs in 2010 (AEB, 2012). Improvements in the management, disease control, nutrition, and genetics of laying hens as well as advancements in egg processing technology over the past 50 years have changed today’s egg quality, composition, and safety; yet few investigations have documented these changes. In 2009, the Food and Drug Administration published a final rule to control *Salmonella* contamination and growth during egg production and through transporation (FDA, 2009). Egg producers with greater than 3,000 hens on site are held to the various requirements of the law. Updated research is needed to serve as a current baseline for evaluation of the application of the new regulations related to egg washing temperatures. In addition, research is needed to aid the egg processing industry to solve the technical problems that have hindered maintaining the consistent quality of the variety of egg products produced for today's market over the egg production cycle of the laying hens.

Collaborative efforts are proposed by the institutions (AL, GA, NC) involved in this proposed project to identify the factors that have impacted egg quality and to determine viable alternatives to maintain and/or improve the quality and safety of shell eggs and egg products. Collaborative efforts for egg research are key for large-scale investigations to be conducted. Research projects between these scientists provide access to the facilities needed to conduct the production research on the farm, egg processing research, and evaluate consumer acceptance of products. NC has excellent layer production facilities, GA has egg processing and bacterial expertise, and AL has long term egg storage and consumer product evaluation experience. It is through the combined efforts of these scientists and their institutional facilities that the current problems related to shell egg quality and safety can be identified and answers provided to egg producers and processors enabling them to maintain consistent quality standards.

Related, Current, and Previous Work:

<u>Poultry Meat Safety</u>

Researchers at NC and SC have developed a new generation of non-degradable and biodegradable packaging films and edible films that have antimicrobial properties effective against bacterial pathogens and spoilage microorganisms common to fresh poultry and meat products and other food commodities. The NC lab was the first to identify and develop a highly effective food-grade biocide formulation (Stevens et al, 1991, 1992ab; Shefet et al, 1995). Their studies also successfully demonstrated the feasibility of using primary packaging films and edible films to deliver bacteriocin formulations (i.e., nisin-containing) to the surface of fresh poultry products. In addition, a nisin-based formulation was incorporated into either agar or calcium alginate gels and applied to *S.* Typhimurium-infected broiler drumstick skin. Mean log reductions in the *Salmonella* populations exceeded 3 to 4.5 log after 72 to 96 hours of exposure to the film at 4 C (Natrajan, 1997). In other preliminary studies biodegradable protein-based films containing lysozyme and/or nisin were formed by casting and heat-set procedures and tested against selected target bacteria. The antimicrobial properties of both inhibitors were retained during the film formation process as documented by the microbial inhibition that was achieved against the target organisms in contact with the film surfaces (Padgett et al., 1995; Dawson et al., 1996, 1997). Recently completed studies on testing of an in-package thermal pasteurization process showed improvement in the safety of a turkey bologna product. These studies determined the decimal reduction times (D-values) for *L. monocytogenes* (124 sec at 61 C and 16 sec at 65 C), *S. typhimurium* (278 sec at 57 C and 81 sec at 60 C), *E. coli* O157:H7 (46 sec at 60 C), and *C. jejuni* (39 sec at 60 C) for packaged bologna. The calculated Z-values were 4.4 C for *L. monocytogenes*, 5.6 C for

S. typhimurium, 13.8 C for *E. coli* O157:H7, and 8.4 C for *C. jejuni*. These data provide the initial documentation in support of the in-package pasteurization of ready-to-eat poultry products and eventual process verification to ensure product safety much like retorted foods are assured of being commercially sterile.

Research was conducted by AL to identify bacteria found in broiler deboning operations. Whole carcasses, skinless breast meat, and equipment were sampled. Among 600 isolates identified, there were 35 different genera, representing 100 different species. Similar genera were found on equipment and breast meat. GA and NC have conducted research to assess the effectiveness of carcass washers and different evisceration techniques. AL and NC assessed the effectiveness of carcass washing systems in their removal of *Campylobacter* in four broiler processing plants. Results indicate washing systems using 3 washers with 50 ppm of total chlorine showed a 0.5 log reduction in *Campylobacter* levels. In these systems an additional TSP rinse reduced levels an additional 1.1 log. Studies were completed by GA to evaluate both rapid methods and novel sanitizing agents for both spoilage and sanitation.

FL and MS determined that marinating chicken breast meat in 2% solutions of sodium metasilicate resulted in at least 1.0 log reduction in *Salmonella* (Sharma et al., 2012). However, sodium metasilicate exhibited no anti-*Listeria* properties in ready-to-eat turkey ham (Sharma et al., 2012). TX, AL, and ARS determined the combination of potassium lactate (2%) and sodium diacetate (0.25%) was effective in inhibiting Listeria growth over a storage period of 12 wk at 4 C (Lloyd et al., 2009). While these two treatments were superior in controlling Listeria growth, sensory panels and quality measurements indicated that the combine treatment of potassium lactate and sodium diacetate would not be a viable solution as it was detrimental to product binding and water-holding capacity. Therefore, future studies need to be conducted to optimize the levels of organic acids used to prevent *Listeria* growth while maintaining product quality.

AL also tested the effect of pH reduction on growth media for *Campylobacter jejuni*. Samples were acidified with citric, hydrochloric, or tartaric acid to pH 4.5-6.5 in 0.5 increments, and then inoculated. In the pH range tested, the inhibitory pH was 4.5 for citric and hydrochloric acid, and pH 5.0 for tartaric. *Campylobacter jejuni* was able to grow in moderately acidic conditions, but type of acidulant affected survival and growth rate. Survival of *Campylobacter* on poultry skin vs. meat was determined by AL. In absence of competing microflora, *Campylobacter* survived well on both media. Ice-crust freezing did not affect survival and temperature abuse also did not affect survival. Surviving populations were slightly higher on skin vs. meat. Rinsing whole or cut-up broiler carcasses prior to chilling to eliminate or significantly reduce the presence of psychrotrophic organisms and *Campylobacter* on retail ready-to-cook poultry was studied by GA and FL. ARS and FL determined that treating chicken breast meat inoculated with *Salmonella typhimurium* with 2.0 and 3.0 kG dosages of irradiation resulted in 4 log reductions in *S. typhimurium* (Sarjeant et al., 2005). ARS and FL determined that nisin at 0.5% could be used as a postprocessing intervention to control *L. monocytogenes* in ready-to-eat poultry products (Ruiz, et al., 2009; 2010). Additional research is needed to better define the ability of *Campylobacter* to survive on poultry meat and skin when treated with antimicrobial substances under commercial processing conditions.

ARS and GA determined that the use of alternative feeds, such as maltodextrin, had no effect on carcass microbial counts. Feathered and genetically featherless broilers (no empty feathers follicles) had no effect on the recovery of *Campylobacter*, *E. coli*, and aerobic bacteria. Sealing the vent before scalding and picking produced picked carcasses that were virtually *Campylobacter* free. A collaborative study with colleagues at NC, and SC was initiated to address the relationship of animal production/waste management practices and the fate of bacterial and viral pathogens that pose a potential risk to humans via contamination of ground and surface waters. We have begun to characterize and assess populations of microbial pathogens and protozoa in commercial poultry and swine waste systems, as well as several new promising waste handling technologies and housing systems. The results from the broiler farm portion of this study indicate that litter *Salmonella* spp. populations and their prevalence in commercial broiler farms were not impacted by individual farm, season, or flock age effects but collectively, they did influence *Salmonella* populations.

<u>Poultry Meat Quality</u>

Currently, it is recommended that broiler carcasses be stored under refrigeration for 4 to 6 hours before deboning to avoid the toughening that accompanies pre-rigor harvesting of broiler breast meat. Since the length of time required for holding carcasses postmortem slows production and is expensive, alternative methods that enable early harvesting or hot-boning of breast fillets have been explored. However, harvesting breast fillets immediately after carcass defeathering or chilling results in meat toughness due to muscle shortening prior to the completion of rigor development (Stewart et al., 1984; Sams and Janky, 1986). Innovative techniques such as pulsed electrical stimulation (Sams et al., 1989), wing restraints or tensioning (Papa and Fletcher, 1988; Lyon et al., 1992; Cason et al., 1997), post-chill flattening (Cason et al., 2002), marination (Alvarado and Sams, 2004), and various combinations of these techniques (Birkhold et al., 1992) have been devised to minimize the length of postmortem aging. However, the above techniques have not been widely used by the processing industry to date, and often have variable results in commercial settings and all require chilling for a minimum of 2 to 3 hours. In addition to the effects of processing on tenderness, factors associated with the bird (age, weight, strain, etc.) have been noted to affect tenderness (i.e. shear parameters) and other meat quality factors (Mehaffey et al., 2006; Brewer et al., 2012a,b). With the large percentage of birds that are over 6 lbs.being processed today, changes in meat quality as a result of the changing bird should be examined.

Tenderness and texture have been noted as the most important factors in consumer perception of palatability or quality of poultry meat products. Therefore, this attribute has drawn the most attention from researchers (Li et al., 2001) and has resulted in many methods for assessing tenderness of breast meat. Instrumental analyses, descriptive analyses, consumer sensory evaluations, or combinations of the tests have been used for assessing meat tenderness. Instrumental methods such as the Allo-Kramer shear compression system, Warner-Bratzler Shear Blade, and Texture Profile Analysis are commonly used within the poultry industry for evaluating tenderness in broiler breast meat (Sams et al., 1990). Descriptive analyses in conjunction with consumer sensory analysis are also methods that researchers use for assessing attributes related to tenderness of poultry meat. These types of tests are very reliable and have been shown to be correlated with instrumental analyses, but can be extensive and exceedingly time consuming. Recently, a shearing technique, the Meullenet-Owens Razor Shear, using a razor blade has been evaluated for monitoring poultry meat tenderness. This technique has similar predictability of tenderness as other common instrumental methods, but requires less sample preparation making it a better alternative because of its ease of use (Cavitt et al., 2001, 2004). This new method along with sensory panels will be useful in assessing meat tenderness of breast fillets that have undergone various processing techniques (early deboning, marination). Furthermore, developing techniques to assess texture of poultry deli loaves is also needed as there is not a common method to do so. Poultry deli meats are common in the retail and foodservice markets and their texture can be impacted by raw ingredient quality and processing methods.

Marination of products with antimicrobial ingredients is also an area of interest as food safety is important. However, using some antimicrobials can negatively affect product quality. Lloyd et al. (2009; AL, TX) determined the combined treatment of potassium lactate and sodium diacetate would not be a viable solution to inhibit Listeria in ready to eat products as it was detrimental to product binding and water-holding capacity. Potassium lactate alone was not detrimental to the texture or water-holding properties, but did result in off-flavor after 2 weeks of storage with the turkey-deli loaves (Lloyd et al., 2009). Future studies should focus evaluate the effect of organics acids on product quality. Researchers at FL determined that marination yield, water-holding capacity and cooking yield increased for chicken breast fillets treated with a sodium metasilicate marinade (Huang, et al., 2011).

Pale, soft, exudative (PSE) meat in swine has been associated with rapid growth rate and antemortem sensitivity to stressors that include environmental holding temperatures (hot or cold), transportation, preslaughter handling practices, stunning methods and postmortem chilling regimes. PSE meat is the result of accelerated postmortem glycolysis that results in a rapid postmortem pH decline while carcass muscle temperatures are still high. This combination can result in muscle protein (myofibrillar and sarcoplasmic) denaturation that leads to pale meat color, poor texture, and decreased water holding capacity (Offer, 1991). This condition has been characterized in both turkey and broiler meat (Owens et al., 2000, Woelfel et al., 2002). Rapid postmortem glycolysis has been observed in swine and turkeys resulting in postmortem pH < 5.8 at 45 min in swine or at 15 min in turkeys compared to a “normal” muscle pH > 6 (Enfalt et al., 1993; Rathgeber et al., 1999). The onset of rigor in the breast fillet (*Pectoralis* muscle) of poultry is faster than in swine muscles (Addis, 1986). Myosin denaturation depended upon the rate of pH decline, final pH, and chilling regime (Offer, 1991). Although the mechanism of water loss in pork has been extensively studied, there has been little research on protein denaturation in poultry. This problem results in large economic losses for the poultry industry. Though there are similarities between PSE pork and PSE-like poultry, there are differences in the species and therefore, differences in the causes of

PSE. More research is needed to understand the root causes of this problem in poultry as well remediation techniques so that economic losses can be decreased.

Researchers at AR and AL have studied white striping in meat and have determined that white striping negatively affects the consumer acceptability of the appearance of broiler fillets and willingness to purchase (Kuttappan et al., 2012a). The condition is highly related to increased growth rate and therefore, increased body weight and age (Bauermeister et al. 2009; Kuttappan et al. 2012b). The white stripes are areas of degenerative muscle fibers and increased lipidosis (Kuttappan et al. 2011) which results in increase fat content and lower protein associated with affected muscle. Research dealing with this growth related myopathy is in its infancy and therefore, much more research is still needed to determine root causes and its impact on meat quality, specifically texture and flavor. Other issues related to increased growth rate and bird size will likely continue to develop as processors continue to focus on large bird processing.

Researchers at AL evaluated carcass defects by differentiating catching from carrying components and determined that carrying was responsible for higher incidence of carcass bruising, green muscle disease and lower yield, but not fillet PSE problems (Moran et al., 2005). Researchers at GA have reported that pH adjustment of ground pale breast fillets did not completely restore all functional properties, but did improve moisture uptake, and cooking yield (Betti and Fletcher, 2005). Researchers at SC have demonstrated that ground chicken thigh meat packaged in an aerobic film had longer color stability in lighted display cases due to retention of oxymyoglobin and slower development of metmyoglobin. Future research will further investigate the genetic component of this meat quality defect. Collaborative efforts are needed because not all institutions possess the same expertise and/or facilities.

<u>Egg Quality and Safety</u>

ARS has developed methods for detecting microcracks in shell eggs, thus increasing egg safety and product quality (Lawerence et al., 2008; Lawrence et al., 2009). This technology has been tested to determine if egg microbiological or quality characteristics are altered due to exposure to the system (Jones et al. 2010). Additionally, ARS has collaboratively worked with NC to determine the effects of alternative housing systems on egg and environmental microbiology (Jones et al., 2011). ARS has also participated in a multi-state examination (with MI, CA, and IA) of the egg safety and quality implication of commercially producing eggs in conventional cage, enriched cage, and aviary production.

Related Multistate Projects:

At AR, a CRIS search was conducted by Casey Owens (June 2012) and there were a few other multistate regional projects that were related, but with different focuses. 1) SDC346: Enhancing Microbial Food Safety by Risk Analysis S-265 encompasses several food commodities (vegetables, fruits, dairy, seafood and meat; fresh and processed) and uses risk based analysis to assess, manage and communicate food safety risks and control measures In contrast, S-1027 focuses on the single commodity of poultry products, including meat and eggs.   2)

NE1042: Optimization of Poultry Welfare and Production Systems for the 21st Century (formerly NE1022). This project is production oriented research including production management (housing, feed, etc.) and environmental quality (e.g., air, water). Measures of animal welfare are addressed. An aspect of the S-1027 focuses on the quality and safety of products resulting from changes in manangement or technologies as a result of animal welfare issues. NC-1042 does not include such quality and food safety aspects. 3) NC1023: Engineering for food safety and quality. This project encompasses many food products (non-specific) and specifically focuses on the engineering aspects of food safety and quality. The S-1027 addresses food safety and quality of poultry products, a type of product likely not addressed in the NC1023 project, and primarily from the biological perspective, rather than from the engineering perpective.

Objectives:

1. Poultry Meat Safety - Production, processing, and packaging safety of poultry meat, through bacterial intervention strategies– chemical, biological, thermal, engineering, and nutritional aspects.

a. To test chemical and natural based interventions for reduction and eliminating pathogenic *(Salmonella, Campylobacter, Listeria*) on raw and processed poultry products.
b. To identify and evaluate biological interventions for eliminating pathogenic bacteria from food contact surfaces, equipment, and products.
c. To assess novel thermal and non-thermal (irradiation) processes for the ability to eliminate pathogens in RTE products.
d. To develop novel engineering and chemical approaches for producing safer poultry products.
e. To assess dietary components and management practices during live production and transporation that may decrease colonization and shedding of pathogens during the production of poultry.

2. Poultry Meat Quality - Improving meat quality through improved bird management/welfare and application of technologies and processes.

a. Meat tenderness/texture: Evaluate changing processing procedure (shortened aging time), simplified instrumental techniques to assess tenderness/texture (e.g., whole muscle, deli), and methods to improve and maintain tenderness through physical or chemical means.
b. Quality defects (PSE-like poultry meat, white striping): Reexamine prodcution and processing procedures and correlate occurrences. Focus on preventing the development of quality defects and remediation PSE-like poultry meat and other poor quality meat. Establish incidence of white striping in industry and continue determining root cause. Evaluate textural sensory attributes associated with meat exhibiting white striping.
c. Technologies and processes: Verification of controlled atmosphere stunning, low atmosphere stunning, air/water combination chilling, and other processes (including new equipment designs, robotics) and their interactions with meat quality, including texture, color, flavor, water holding capacity, and blood splash. Establish a

relationship between improved bird welfare and meat quality. Standardize methodologies among labs for assessing meat quality.

3. Egg Quality and Safety - To identify methods and procedures to improve and maintain the quality and safety of shell eggs and egg products.

a. Determine impact of alternative housing methods on egg quality and safety.
b. Assess the effectiveness of alternative sanitizing agents on shell eggs.
c. Determine environmental and biological factors impacting the safety of eggs.
d. Determine the applicability of imaging technology for assessing eggshell integrity and shell egg internal components and quality.

Methods:

Poultry Meat Safety

Influences of grain particle size and insoluble fiber content on *Salmonella* colonization and shedding in turkeys fed a corn-soybean meal diet (NC, SC) will be evaluated. The effects of Immustim® and Protimax® on *Campylobacter jejuni* and *Salmonella* Typhimurium populations in broilers (NC, SC) will be evaluated. Using the poultry production resources located at NC, turkeys will be reared according to the above outlined treatments and then subsequently processed and split cecal and fecal samples analyzed at NC and SC for the presence of *Campylobacter* and *Salmonella* intestinal colonization, respectively. Studies will be conducted to evaluate the efficacy of acidified sodium chlorite, organic acids, ~~Tasker Blue,~~ and other disinfectants in poultry drinking water against food-borne pathogens (AL, ARS, GA). Pathogen (*E. coli*, *Salmonella*, and *Campylobacter*) dissemination in an integrated poultry production complex will be studied by monitoring broiler farms. Intervention strategies for reducing pathogenic, indicator, and spoilage bacteria from poultry carcasses will be investigated. Environmental isolates will be correlated with those recovered from post-chill carcasses by bacterial ribotyping.

Effect of processing technologies such as pre-scald brushes, carcass washers, online reprocessing systems, and chiller interventions on *Campylobacter* and *Salmonella* contamination in large broiler processing plants will be researched (AL, ARS, GA, NC). As a means of estimating the prevalence of contamination across a multitude of broiler processing plants located in the southeastern United States, carcasses from multiple plants located in each of these states will be monitored for these two pathogens and the data shared among the cooperating states. Multiple collaborative publications from this cooperative project are anticipated. *Listeria monocytogenes* will be subtyped from a poultry further processing plant over a period of months to determine if the source of *L. monocytogenes* contamination is from the raw product or from an endemic source inside the plants such as the floor drains (AL, ARS, NC, SC). Similar to the first project described above, the incidence of contamination survey data collected from each cooperating state will be shared among the group with the goal of producing a comprehensive summary. The elimination of *L. monocytogenes* in packaged, ready-to-eat poultry products by combining heat with lysozyme and/or nisin and MAP and natural antimicrobials will be investigated (GA, NC, SC, FL and MS). Efficacy of conveyor belt materials containing inhibitors for controlling food-borne pathogens in the processing environment will be evaluated (GA, NC, TX). GA, ~~and~~ NC, and TX will be conducting studies to determine if the risk of microbial cross-contamination using conveyor belts containing a microbial inhibitor can be reduced. Data will be compared from the separate studies and the optimum belt treatments identified and further evaluated during in-plant trials conducted within each state.

Penetration of *Salmonella* spp. into whole muscle during vacuum marination, the effect of water activity on the thermal inactivation of *Salmonella* during heating of meat, and the effect of meat product structure on thermal inactivation of *Salmonella* during heating will be determined (AL, MI, NY, TX, WI). GA ~~and GU~~ will evaluate the microbiological conditions of moisture-enhanced chicken breast prepared at a poultry packing plant. ~~Detection of *Campylobacter jejuni* in naturally contaminated chicken meat by melting-peak analysis of amplicons in real-time PCR will be evaluated (GU). GU will conduct studies on distribution of *Salmonella* during tumbling of fresh chicken breast meat.~~

The ability of various food-grade powders to adsorb and release nisin activity will be evaluated (NC, SC). Furthermore, a multi-hurdle approach using natural antimicrobial films and carriers with in-package pasteurization for sliced ready-to-eat poultry products will be evaluated (GA, NC, SC). Given the packaging expertise at SC, packaging films containing or coated with adsorptive powders containing nisin will be generated by the SC collaborators and subsequently tested by colleagues in NC for their efficacy against *Listeria monocytogenes* on ready-to-eat poultry products. By increasing the efficacy of the surface pasteurization process using antimicrobials, the probability that *L. monocytogenes* will survive in the product is expected to be greatly reduced or eliminated. An additional benefit that will be collectively explored at both institutions is determining the impact of these intervention strategies on extending product shelf life. Based on previous successful studies conducted in NC on food safety applications involving eggshell membranes, further collaborative studies with GA will be conducted to explore practical applications for applying these membranes to different muscle food systems.

Poultry Meat Quality

Biological factors impac~~i~~ting meat quality – AR, AL and TX will evaluate production and processing techniques that may reduce PSE and white striping incidence (e.g., stunning, scalding, rapid chilling, etc.). AR, TX, and WI will evaluate the incidence of PSE and white striping as well as other quality defects, muscle color, water holding capacity, gel strength, protein functionality, oxidation and texture while AL and AR will correlate occurrence and physical dimensions with age, sex, strain, and dietary and management factors. AL and AR are positioned near primary breeder companies and have facilities for grow-out and processing. AR will also investigate relationships between tenderness (and meat quality) and physical/biochemical attributes of broiler breast meat. Information among institutions will be shared/combined for complete analysis.

Development/Preparation of value-added poultry products using marination, fermentation and other processes - Studies will focus on functionality of meat when subjected to various processes (e.g., controlled atmosphere stunning, low atmosphere stunning~~.~~, p~~P~~ortioning, etc.) and/or ingredients; this will include the improvement of defective meat such as PSE meat or tough meat. Color, water holding capacity, texture, gel strength, flavor, and lipid oxidation will be measured using both instrumental and sensory techniques to determine consumer acceptability as well as characteristics of economic interest (AL, AR, FL, NC, SC, TX, WI). AL, AR, FL and TX will evaluate processing technologies as well as novel ingredients on basic meat quality characteristics. AR, AL, NC~~GA~~ and TX will collaborate to assess the combination of these processing technologies that will add value to poultry products. Products from various studies will be shipped to WI for assessment of lipid oxidation. Furthermore, SC and GA will evaluate packaging technologies and send samples for analysis to collaborators. AR and ARS~~GA~~will also conduct sensory analyses (descriptive and consumer sensory methods) of the cooked meat or finished meat products as the ultimate measure of consumer quality and acceptability.

Standardization of methodology for evaluating meat color, pH, imaging technology and sensoryamong various laboratories – Meat quality data is often collected and reported by researchers. There has been some question as to the methodology that various laboratories are using to measure color and pH. In an attempt to standardize methodology for measuring color, a variety of color standards will be evaluated by various laboratories using either a Minolta or Hunter colorimeter. Analysis of different pH methods will also be conducted. Variation between laboratories and instruments will be determined. A recommendation for standardized methodology will be developed (AL, AR, ARS ~~(GA)~~, NC, SC, TX, WI) while imposing digital imagery. Meat tenderness of the large broiler sector will be correlated with sensory panels as the tenderness of these birds is beyond the range studied in the development of the MORS method (AR and ARS).

Egg Safety and Quality

~~—~~Egg safety and quality research will be conducted by AL, ARS, NC, NY, SC, and TX. AL, ARS, NC, NY, SC, and TX will evaluate ways to improve the quality of shell eggs and egg products. Egg quality will be evaluated through established subjective and objective methods, such as Haugh unit, albumen height, egg weight, shell strength, and vitelline membrane strength. Additional efforts will be initiated between ARS and NC to develop more advanced rheological methods for assessing egg and egg product quality. AL, NC, and SC will be looking at the factors associated with functional deficiencies in egg products. AL and NC will be attempting to identify the changes in functionality of eggs from hens over their life cycle and evaluating the proximate composition changes in eggs produced by hens over a two-year life cycle. NC will provide the eggs to be tested and conduct production related evaluations. AL will conduct processing, composition and functionality testing on eggs provided by NC. AL will also lead the effort amongst the group to correlate functionality and sensory analysis of eggs and egg products. ARS scientists will evaluate the effectiveness of sanitizing agents and look for alternative agents for sanitizing shell eggs. AL, ARS, NC, and SC will be evaluating factors impacting the safety of eggs and egg products. ARS will examine the impact of alternative housing practices on egg quality and safety. SC and GA will compare the microbiologial status and quality of eggs porduced from hens fed a soy-free and statndard soy diet along with free-range and caged environments.

Summations of yearly research productivity will be prepared by objective leaders following the yearly meeting for inclusion of the summaries in the annual project report. Objective leaders will identify the subsequent year's goals to focus collaborative research projects. The compilation of the yearly summaries will be used to establish new objectives for the future project proposal in 2017.

Measurements of Progress and Results:

Outputs:

- Research activities will continue to result in publication of research findings in peer-reviewed journals, text-book chapters and books, abstracts, published proceedings, industry partner reports, patents, popular press articles, lecture and laboratory procedures.
- Meat tenderness evaluation methods will be updated to include fillets in tougher ranges (not previously included). Deli meat texture will also be assessed and correlated with sensory to determine an instrumental test for predicting texture.
- Effective product formulations will be developed for remediation of PSE-like meat.
- A greater understanding will be gained on the use of technologies such as controlled atmosphere or low atmosphere stunning and air chilling and their interaction with rigor development and meat quality and safety as well as with common processing practices of today.
- Optimization of packaging technology to maintain high product quality.
- Quantification of effectiveness of sanitizing compounds on shell eggs.

Outcomes or Projected Impacts:

- Exclusion of microbial pathogens and spoilage microorganisms from ready-to-eat poultry products by a simple non-evasive process, such as described in this study, achieved in a practical and economical way such as an in-package process, could decrease the incidence of human illness and the attendant costs. The combination of in-package pasteurization with natural preservatives could also assure the safety and quality of poultry products throughout retail marketing.
- Documentation and validation of the conditions required to produce a safe ready-to-eat poultry product.
- Evaluating inhibitory agents with thermal treatments coupled with existing modified atmosphere packaging technology for use in reducing pathogens on poultry products will be useful for gaining acceptance of these processes by regulatory agencies.
- By teaming with commercial film producers (Cryovac, Sealed Air Corp.) the data generated in our proposed study can be used to develop commercially valid processes that will ensure product safety while maintaining quality.

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- The measurable outcome of the project will be a multi-media poultry processing curriculum with broad applications including in-class delivery through traditional classes or workshops, self-study, and distance learning formats. This curriculum will address a national and international education need, involve a collaborative working relationship among universities to enhance program quality and supplement available resources, and will produce benefits that will transcend the project duration.

- Development of recommendations for maximizing the quality and safety of poultry meat, eggs and egg products.

Milestones:

- A study will be conducted over a two-year period with the first objective (development and testing of the in-package pasteurization process) addressed during the first year and the second objective (shelf life studies) addressed the second year.
- Scientific presentations will be made in both years with the publications complete and ready for submission for review at the end of the second year. The only time-linked accomplishments associated with this research involve the rate at which the FDA and USDA/FSIS approve the use of these technologies. Once research has been completed, the technology must go through a comprehensive evaluation by regulatory authorities prior to implementation.
- An appropriate method for assessing texture of deli meat will be developed for use in processing plants in the industry for quality control practices.
- Sorting recommendations for PSE and white striped meat will be developed using image technology.
- Identification of preslaughter procedures most sensitive to creating grade defects and harmful to the bird's welfare should be at hand.
- Identification of alternative egg processing sanitization procedures (temperatures and chemicals) and their approval by FDA will need to precede the field-testing in commercial facilities.

Projected Participation:
See Attached Appendix E

Outreach Plan:

The findings of these collaborative research projects will be presented as outlined above under Outputs through traditional outreach efforts including refereed scientific articles and non-refereed publications for both industry and consumers, including targeted articles and fact sheets. Most abstract and journal publications containing current research are available through journals with worldwide distribution via internet access. Many research projects involve industry partners who are frequently updated on research progress and are provided in depth final reports and presentations that contain recommendations from the research. In addition, the results and applications of research projects will be presented frequently to public audiences and the membership of international, national and regional poultry producers and processors associations, national research societies, and federal and state regulatory governmental agencies at meetings and workshops. These meetings are well attended by consumer advocates, trade journal and news reporters, poultry and allied industry personnel, research scientists, and government regulatory personnel. Findings will be disseminated within station institutions through annual reports and presentations to graduate students and faculty attending our respective departmental seminars. Curriculum containing current research will be delivered in a variety of formats including in-class lecture, distance education, and self-study for undergraduate students. There is high employment demand for students from cooperating institutions in the poultry processing and food processing industries where their acquired knowledge can address daily concerns on the job site. Each year's results are also presented in written and oral format to the members of this multi-state regional project at the annual meeting. Information will be available through the NIMSS system (***nimss****.umd.edu/)*. Press releases telling about the site's features will be distributed through various internal extension mechanisms, including those at USDA/FSIS, to assure that appropriate audiences are aware of the site. An updated, consumer/industry friendly web site, which may incorporate some of the presentations, will also be developed by AR.

Organization and Governance:

Current Officers: Casey M. Owens, AR, Chair; Mike Musgrove, ARS, Vice Chair; TBA, Secretary; Paul Dawson, SC, Past Chair. Officers are elected by the participating membership at the annual meeting and serve two-year terms that are progressive from Secretary to Vice Chair to Chair.

Current Objective Leaders: Scott M. Russell, GA – 1. Poultry Meat Safety; Casey M. Owens, AR – 2. Poultry Meat Quality; Mike Musgrove, ARS – 3. Egg Quality and Safety.

Internal Linkages:

AL, AR, CA, FL, GA, IA, MI, MS, NC, NY, SC, TX, WI

External Linkages:

ARS~~, University of Guelph Canada (GU)~~

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