

(CONFIDENTIAL, NOT FOR PUBLICATION)

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**2006 PROGRESS REPORT:**

**OBJECTIVE 4:**      Production and Processing Factors Impacting the Safety of Poultry Products

**Number 1: Preslaughter Activities**

**Effects of Nutrition and Waste Management Technologies on Pathogens in Animal Excreta (Brian Sheldon, Peter Ferket, Mike Williams, Xin Li - NCSU and Ohio State University)**

A collaborative study with colleagues at Ohio State University has continued to address the relationship of animal production/waste management practices and nutritional interventions to the fate of bacterial and viral pathogens that pose a potential risk to humans. Our work has centered on the impact of nutritional strategies and in particular grain particle size and insoluble fiber on its ability to modulate the gastrointestinal tract microflora and in particular *Salmonella*. Other studies have centered on alternative housing systems such as the caged broiler system for reducing the level of microbial contamination on broilers (i.e., Broilermatic Cage Growing System). Nutrition and dietary components potentially affecting the production, frequency and fate of pathogens in excreta and following treatment and land application are also being investigated.

**Turkey Trials: Influence of Grain Particle Size and Insoluble Fiber Content on *Salmonella* Colonization and Shedding of Turkeys Fed Corn-Soybean Meal Diets (Brian Sheldon, Fernanda Santos, Aneal Santos, and Peter Ferket)**

Previous studies have shown that changes in feed formulation practices can impact the anatomy and physiology of the intestinal tract of poultry. Besides physical changes in the diet, variations in the composition can also alter the avian intestinal microflora. This study was conducted to determine the impact of feeding partially ground corn or insoluble fiber to 0-28 day old turkeys on intestinal development and its ability to modulate *Salmonella* cecal colonization and

fecal shedding. Nicholas toms reared in cage batteries were assigned to 1 of 3 treatment diets: ground corn-SBM (GC, TRT 1), coarse ground corn-SBM (CC, TRT 2), and 4% wood shavings + ground corn-SBM (SC, TRT 3). A 3-strain cocktail of nalidixic acid-resistant *Salmonella enterica* serotypes Hadar, Javaina, and Typhimurium was orally-gavaged into each poult at placement. Cecal and fecal *Salmonella* populations were estimated on days 7, 14, 21, 28, and 1, 14, 28, respectively. Growth performance and intestinal weights and lengths were also measured. The diets had no impact on *Salmonella* cecal or fecal populations. Cecal populations at 7d averaged 5.9, 6.3 and 6.5 log CFU/g for TRT 1, 2 and 3, respectively. At 28d, *Salmonella* cecal populations decreased by 3-logs across all treatments ( $P < 0.0001$ ). At the end of the experiment body weight, body gain and feed conversion ratio were not impacted by the dietary treatments. However, poult consuming the SC diet had lower feed consumption (FC) at 14 days than those fed the GC and CC diets (231 vs. 243 and 252 g,  $P = 0.001$ , respectively). The CC and SC diets produced heavier gizzards than the GC diets throughout the study. The CC diet resulted in heavier relative gizzard weights at 28d than among the GC and SC diets (30 vs. 28 and 22 g/kg, respectively,  $P < 0.0001$ ). In contrast, the SC treatment reduced the mass of the small intestine relative to body weight, especially the jejunum. Although dietary inclusion of coarsely ground corn and wood shavings had no detectable influence on *Salmonella* colonization and fecal shedding, it had no adverse effect on growth performance yet improved gizzard and intestinal development, which could have positive effects on gut health.

**Broiler Trials: Influence of housing system, grain type and particle size on *Salmonella* colonization and shedding in broilers fed triticale- and corn-soybean meal diets (Brian Sheldon, Fernanda Santos, Aneal Santos, and Peter Ferket)**

This study focused on determining the effect of feeding whole grains and housing design on cecal *Salmonella* colonization, growth performance and carcass yield of broilers fed triticale or corn/SBM-based diets. Broilers reared either in a cage-based house (Broilermatic® System) or a conventional house (litter floor) from 0-42 d were assigned to 1 of 4 dietary treatments (trt): 1) ground corn-SBM (C, 560 $\mu$ ), 2) coarse ground corn-SBM (CC, >1700 $\mu$ ), 3) ground triticale-SBM (T, 560 $\mu$ ), and 4) whole triticale-SBM (WT). A 4-serotype cocktail of *Salmonella enterica* was orally-gavaged into each chick at placement. Cecal populations were estimated on 7, 14, 21, 28, 35, and 42 d. Growth performance was measured on 14, 28 and 42 d. Broilers responded differently to the dietary treatments according to housing system. At 42 d, birds reared on litter had better body weights when fed ground grain (2.87, 2.86, 2.73, 2.69 kg; trt 3, 1, 4, 2, respectively;  $P=0.004$ , no statistical difference between T and C); however, broilers reared in the Broilermatic cages were heavier when fed T (2.75, 2.67, 2.65, 2.61 kg; trt 3, 4, 2, 1, respectively;  $P=0.01$ , no statistical difference between WT, CC and C). Feed conversion ratio (FCR) was influenced by housing design. Compared to the Broilermatic system, raising broilers on litter improved the 1-42d FCR (1.71 vs. 1.81 g/g,  $P<0.0001$ ). Independent of housing system, relative eviscerated carcass weights of birds fed T were equivalent to the C fed birds and heavier than CC and WT fed broilers (0.764, 0.760, 0.752, 0.752 g/g, respectively;  $P=0.01$ ). Feeding whole/coarse ground grains decreased cecal *Salmonella* populations in broilers (3.8, 3.9, 4.4, 4.4 log MPN/g; trt 2, 4, 1, 3, respectively;  $P=0.05$ ). Housing type also influenced cecal *Salmonella* populations. At 42d, birds reared on litter had lower populations than broilers reared in cages (3.8 vs. 4.4 log MPN/g,  $P=0.002$ ). In conclusion, triticale appeared to be a good alternative feed ingredient to corn resulting in improved body weights and reduced *Salmonella* colonization. Moreover, raising broilers on litter greatly reduced cecal *Salmonella* populations.

**Impacts:** The information gained from these two studies can be a useful tool for developing new and effective control strategies for reducing pre-harvest *Salmonella* contamination populations through a multiple step intervention program that includes dietary changes and changes in housing design. The first study demonstrated that changing feed particle size as well as inclusion of more insoluble fiber into the diet improved the feed conversion ratio during the critical 7 day post-hatch period and did not adversely impact body weight. Moreover, these experimental diets also increased gizzard weights while small intestine weights declined. Further studies are required to determine if these alternative production strategies influence intestinal colonization and shedding of *Salmonella* in turkeys. Findings from the broiler study revealed that feeding coarse ground corn to broilers significantly reduced cecal *Salmonella* populations whereas raising birds on traditional dry litter floor systems in contrast to a caged system also significantly reduced cecal *Salmonella* populations. When pathogen populations are reduced during the pre-harvest phase of production, foodborne pathogen prevalence and populations entering processing plants or the environment should also be reduced, thus reducing their subsequent transmission risk to humans and other animals. The current high costs of processing interventions used to meet the USDA *Salmonella* Performance Standards may be reduced if alternative cost-effective practices such as described in these two studies are identified and applied.

**North Carolina Layer Performance and Management Test (NCLP&MT). (Collaborators include D. R. Jones, USDA-ARS Athens, GA; P. A. Curtis, Auburn University)**

The purpose of the test is to provide Layer Strain evaluations in under common husbandry and environmental conditions to enable equal evaluation of the hen performance by the producers in North Carolina and other locations in the world. This is the only strain comparison test of this type and size remaining in the world. As such collaborations with other researchers have developed to look at strain differences or the impact of husbandry practices. This extension project has expanded to develop and to provide scientific answers to issues relating to the impacts of the production parameters and management on egg quality, functionality and safety throughout the production chain. Much of the research in this program has centered on the practice of molting, which is widely used in the egg industry, and in turn has helped industry organizations establish applicable guidelines which may mitigate potential negative impacts on microbial shedding.

This program deals with egg production type chickens in the production environments and to provide insight to the laying hens under different cage densities and husbandry practices (molting). I have been examining alternative molting programs for their effectiveness as related to the industry standard program of fasting. These experiments included a survey of the microbial shedding of laying hens subjected to alternative molting programs. In addition, the integration of an egg solids study, for the breaking industry, along with functionality and egg safety studies were recently completed.

**Impact Of White And Brown-Egg Layer Strains and Molt on Size Distribution and Egg Quality During the Second Production Cycle. (in cooperation with P.A. Curtis, Auburn University)**

The production, quality, and egg sizes of the commercially available layer strains vary with respect to the specific strain examined, yet few studies continuously document these differences. In this study, 9 white egg (WES) and 3 brown egg strains (BES) were equally represented and housed at a density of 413 cm<sup>2</sup>. The white and brown egg strain feeding programs were segregated in order to meet the nutritional needs of the two different groups. At 66 wk the hens were divided into three groups; non-molted (NM) group; non-fasted molt (NF); and fasted molt (FR) for 4 wk. The remaining husbandry practices were the same for each group and identical to those used in the 35<sup>th</sup> North Carolina Layer Performance and Management Test. Every 28 day period from 70 through 110 wk egg samples from the previous 24 h were collected from each replicate. The eggs were weighed and graded in accordance with USDA standards for shell eggs. Haugh units and other internal quality measurements were taken on egg samples collected every other period.

Strain had the greatest influence on egg weight with the differences illustrated in changes within the distribution of eggs from the smaller egg sizes of mediums and large to the extra large classification. In the WES the W-98 produced more ( $P < 0.05$ ) 89.1% extra large eggs while the W-36 and B-300 produced 69.4 and 65.1%, respectively. In the BES, egg weights were the heaviest ( $P < 0.05$ ) for the Bovans Brown and Goldline at 67.7 and 67.8 g, respectively while the egg weight for the Hy-Line Brown was 66.5 g. This egg weight shifted the egg size distribution from large to extra large for the Bovans Strains. In both WES and BES, the NM control hens had the highest percentage of medium eggs while the two molt treatments were no different. In the WES molting by either method resulted in fewer Grade B and Cracked eggs than in the NM control group. In the BES percent Grade A eggs for the NM, NF, and FR molt programs were 85.9, 88.3 and 90.5%, respectively. The shift in egg size is inversely related to the percent Grade B for the same molt treatments. There was no effect of molt treatment on cracks or loss eggs. Strain selection within the production operation can significantly affect the size of the egg produced while molting influenced the egg quality.

**A Comparison of Egg Solids in Selected Strains of Layer Hens: Examining the Impact of Hen Age, Egg Age, Storage Conditions and Forced Molt through the 2<sup>nd</sup> Cycle. (In collaboration with P. A. Curtis, Auburn University)**

Feed consumption and feed conversion for white egg layers were not significantly affected by strain. The eggs per hen housed were influenced by the strain with a difference of 18.6 eggs from the highest producing stock to the lowest. This was not reflected in the percent hen day production between the strains, and therefore may in some

cases be a result in the differences in mortality between the strains. All strains reach 50% production by 138 D of age, but the variation between the strains was as high as 8 days. Egg weight and subsequent egg size distribution was influenced by the strain. There were no differences in the percent of large egg produced. The differences were related to a shift, predominantly related to small and medium sizes and the extra large percentages. Those strains with the heaviest eggs had the greatest percentage of extra large eggs. The percentage of Grade A eggs was not influenced by strain. The percent of Grade B and loss eggs was different between strains. The egg income and feed expenses are significantly different between strains. The combination of high egg income and low feed costs resulted in as much as \$1.08/hen difference. Each of the solids measurements were significantly impacted by strain of the hen, however, the changes in solids were not consistent between the different solid measurements. The interaction of strain and hen age on the percent of albumen solids shows that the strains' albumen secretion is different as the hens' age. Not all strains had continually decreasing albumen solids. The percent of albumen, yolk and whole egg solids significantly changes as the hen ages. Albumen solids generally decreased as the hen aged. Yolk generally increased over the production cycle, however, there were a few periods where yolk solids decreased. Whole egg solids increased through day 266 then plateaued at approximately 24.9%. The 21 day storage period resulted in a significant shift in the percent albumen and yolk solids. The albumen solids increased and the yolk solids decreased. Surprisingly, storage did not impact the whole egg solids. There was a significant interaction between hen age and storage temperature after 21 days of storage for yolk and whole egg solids, but not for albumen.

Even though the strain body weights were different after the random allocation to the molt treatments the average hen weights and weight losses for treatments were not different. The strain of hen did not impact the feed consumption during the 2<sup>nd</sup> cycle. The HH eggs were significantly increased in the molted hens over the non-molted hens. There was also a 8.3% reduction in mortality in the NF and FR molted hens. During the 2<sup>nd</sup> cycle, the strain had the greatest influence on egg weight. The strain of the hen did influence the albumen, yolk and whole egg solids during the 2<sup>nd</sup> cycle as it did in the 1<sup>st</sup> cycle. In general, the values were lower for the 2<sup>nd</sup> cycle than for the first. The yolk solids did not necessarily increase or decrease in response to corresponding changes in albumen solids. As with the 1<sup>st</sup> cycle, the age of the hen significantly influenced the percentage of albumen and yolk solids. Whole egg solids were stable throughout the 2<sup>nd</sup> cycle. Albumen solids were 0.5% higher in eggs from molted birds. Yolk and whole egg solids were not impacted by molting. The duration of the storage had a significant impact on all solids measurements. Albumen solids decreased throughout the 2<sup>nd</sup> cycle with stored eggs having highest solids. Yolk solids decreased during storage. However, as the hen aged the differences between the fresh and store yolk solids diminished. Whole egg solids were not affected by a 4°C storage for 21 days, but did increase when storage temperature was increased to 20°C.

### **National Egg Products School (In Collaboration with AR, NC, SC, and TX)**

The National Egg Products School was held July 31 through August 3 in Fayetteville, AR. The school offered "hands on" laboratory experiences to assist participants in understanding the functionality characteristics of egg products. The school will continue to be offered on an annual basis at selected locations across the country. The 2006 school had faculty from Auburn University, North Carolina State University, and the University of Arkansas. The National Egg Products School Advisory board is made up of representatives from industry, trade organizations, government and academia.

### **National Egg Quality School (In Collaboration with AL, AR, TX, NC, IA, IL, KY, and Egg Councils in IA, IN, TX, KY as well as State Depts. of Agriculture from AR, MD, NC, and VA)**

The shell egg industry is in need of continuous training for production and processing personnel in order to keep them current with today's changing technologies and regulations in production, processing, and distribution of eggs for the consumer. The school organization is a tax-exempt, non-profit organization whose main aim is to provide students from the industry the latest information about egg quality and the factors affecting quality. The training begins with the basics of egg formation then, egg quality factors and the components which may affect quality. The students are also trained in USDA grading and regulatory changes. Individualized instruction and "hands on" laboratories are the trade mark of the school. The students are divided into small work groups with an experienced instructor who works with them on an individual basis. To earn a certificate the students will have a written and lab practical exam.

## **Impacts:**

### **North Carolina Layer Performance and Management Test (NCLP&MT).**

The NCLP&MT reports are sent to all the producers in North Carolina and an additional 330 reports are sent to producers and industry representatives throughout the US and 16 different countries. The primary breeders, egg producers, and egg breaking companies are utilizing the test in increasing intensity to compare and evaluate the impact of strain, environment, and management have on the egg solids, functionality, and safety. This can lead to a shift in layer strain purchases and management in production facilities on the part of the breaking companies to enhance their product properties thereby enhancing sales to egg product purchasers.

### **A Comparison of Egg Solids in Selected Strains of Layer Hens: Examining the Impact of Hen Age, Egg Age, Storage Conditions and Forced Molt through the 2<sup>nd</sup> Cycle.**

The solids components in liquid egg products are very important for the Liquid Egg Products Industry in order to satisfy their customer requirements for functional properties. If solids are influenced by strain, or age of the hens producing the eggs they need to understand these influences which will enable them to constantly blend a uniform product. These studies are the first examining the egg products in this manner.

### **Impact of white and brown-egg layer strains and molt on size distribution, and egg quality during the second production cycle.**

The strains are under continuous selection for improved production and egg quality. Therefore, as each NCLP&MT is developed the influence of strain effects must be evaluated in order to keep producers informed of genetic changes.

### **National Egg Products School:**

The National Egg Products School provides breaking plant personnel quality assurance supervisors, and middle management within the egg breaking industry current information on what constitutes egg product quality, how to measure it, and important issues facing the egg industry in the region.

### **National Egg Quality School:**

Students from numerous states, US territory, and internationally have joined more than 5,670 alumni from around the world who have attended this school over the past 77 years. This school continues its emphasis on the preservation of shell egg quality and ensuring that consumers today are purchasing the highest quality product. In addition, emerging issues of microbial quality, food safety, and HACCP plan development are topics important to the industry and are included in the school. One goal of the school is to bring in food handlers from across the country and introduce them to egg quality and how to preserve it.

## **WORK PLANNED FOR NEXT YEAR:**

### **OBJECTIVE 4. Production and Processing Factors Impacting the Safety of Poultry Products**

#### **Number 1: Preslaughter Activities**

**Effects of Nutrition on Pathogens in Poultry (NCSU - Sheldon, Ferket, Williams, Fernanda Santos; Clemson - Dawson):** Influence of grain particle size and insoluble fiber content on *Salmonella* colonization and shedding in turkeys fed a corn-soybean meal diet (NC and SC) will continue to be evaluated. The effects of Immustim® and Protimax® on *Campylobacter jejuni* and *Salmonella* Typhimurium populations in broilers (NC and SC) will be evaluated. Using the poultry production resources located at North Carolina State University, turkeys will be reared according to the above outlined treatments and then subsequently processed and split cecal and fecal samples analyzed at NCSU and Clemson for the presence of *Campylobacter* and *Salmonella* intestinal colonization, respectively.

## **Number 2: Broiler and Egg Processing**

**Strategies to Control *Campylobacter*, *Salmonella*, and *Listeria monocytogenes* at the Processing Plant (Brian Sheldon – NCSU; Paul Dawson – Clemson; Scott Russell – UGA; Curtis - AL):** Effect of carcass washers on *Campylobacter* and *Salmonella* contamination in large broiler processing plants will be examined (NC, AL, and GA). 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, GA, SC, and NC). Similar to the first project described above, the incidence of contamination 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 will be investigated (NC, SC, and GA). Efficacy of conveyor belt materials containing inhibitors for controlling food-borne pathogens in the processing environment will be evaluated (NC and GA). NC and GA 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.

**Improving Egg Quality, Functionality, and Safety (Ken Anderson – NCSU; Pat Curtis – AL; Deana Jones – USDA-ARS, GA)** Work will continue on evaluating the impact of hen strain differences on egg quality, functionality, and safety and on the impact of integrating egg quality, functionality and safety research with production and management practices research.

## **Number 4: Packaging:**

**Eliminating *Listeria monocytogenes* in Packaged, Ready-to-Eat Poultry Products by Combining Heat with Lysozyme and/or Nisin and MAP (Brian Sheldon and Paul Dawson – Clemson; Kevin Keener - IN):** NC, SC, and IN will continue investigating the application of non-thermal plasmas for the treatment of surface contamination of poultry products (raw, partially cooked, and fully cooked) and packaging films. Experiments will determine non-thermal plasma's ability to reduce bacterial contamination based on plasma gas composition (nitrogen, oxygen, helium), surface type (skin, muscle, non-food), and type and level of pathogen contamination (*Salmonella*, *Listeria*, *Campylobacter*).

### **Education:**

Continue working with the National Egg Quality School.

Continue participating in the planning and implementation of training innovations for the National Egg Products School.

### **PUBLICATIONS (2006):**

#### **A. Journal Articles:**

Ahlborn, G.J., D.A. Clare, B.W. Sheldon, and R.W. Kelly. 2006. Identification of eggshell membrane proteins and purification of ovotransferrin and  $\beta$ -NAGase from hen egg white. *The Protein J.* 25:71-81.

Ahlborn, G., and B.W. Sheldon. 2006. Identifying the components in eggshell membrane responsible for reducing the heat resistance of bacterial pathogens. *J. Food Prot.* 69:729-738.

Keener, K. M., K. C. McAvoy, J. B. Foegeding, P. A. Curtis, K. E. Anderson, J. A. Osborne, and D. J. Bush. 2006. Effect of testing temperature on internal egg quality measurements. *Poultry Sci.* 85:550-555.

#### **B. Abstracts:**

Anderson, K.E., L.K. Kerth, V.K.Kreuschmar-McCluskey, and P.A. Curtis. 2006. Impact of white and brown-egg layer strains and molt on size distribution and egg quality during a second production cycle. Poultry Sci. Suppl. 85: 100-101. (abst)

Anderson, K.E., L.K. Kerth, V.K.Kreuschmar-McCluskey, and P.A. Curtis. 2005. Impact of Strain on environmental and fecal microbial load and Salmonella prevalence during a single production cycle. Poultry Sci. Suppl. 84: 76. (abst)

Anderson, K.E., L.K. Kerth, V.K.Kreuschmar-McCluskey, and P.A. Curtis. 2005. Impact of White and Brown-egg layer strains on egg quality and size distribution during a single production cycle. Poultry Sci. Suppl. 84: 78. (abst)

Caudill, A.B., P.A. Curtis, D.R. Jones, M.T. Musgrove, K.E. Anderson, and O.A. Oyarzabal. 2005. Effects of cool water washing of shell eggs on interior quality. Poultry Sci. Suppl. 84:77. (abst)

Caudill, A. B., P.A. Curtis, D.R. Jones, M.T. Musgrove, K. E. Anderson, and L. K. Kerth. 2006. Effects of cool water washing of shell eggs on Haugh unit, vitelline membrane strength, aerobic bacteria, yeast, and mold. Poultry Sci. Suppl. 85: 100. (abst)

Curtis, P.A., Kerth, L.K., and K.E. Anderson. 2005. Impact of strain on egg quality and composition during a single production cycle. Poultry Sci. Suppl. 84:78. (abst)

Curtis, P. A., L. K. Kerth, and K. E. Anderson. 2006. Albumen quality and functionality from eggs produced by hens from 5 layer strains over two production cycles. Poultry Sci. Suppl. 85: 135-136. (abst)

Kerth, L. K., P. A. Curtis, and K. E. Anderson. 2006. Functionality and quality of whole egg and yolk from five different layer strains over two production cycles. Poultry Sci. Suppl. 85:136. (abst)

Kerth, L.K., P.A. Curtis, and K.E. Anderson. 2005. Effect of layer hen strain on egg weights and solids during a single production cycle. Poultry Sci. Suppl. 84:78. (abst)

Kerth, L.K., P.A. Curtis, and K.E. Anderson. 2005. Layer strain impact on functional properties of eggs during a single production cycle. Poultry Sci. Suppl. 84:78. (abst)

Kreuschmar-McCluskey, V.K., K.E. Anderson, P.A. Curtis, and L.K. Kerth. 2005. Influence of hen age on shell egg exterior, interior, and contents microflora and Salmonella prevalence during a single production cycle. Poultry Sci. Suppl. 84:76. (abst)

Kreuschmar-McCluskey, V.K., P.A. Curtis, K.E. Anderson, L.K. Kerth, and O. A. Oyarzabal. 2006. Influence of hen age and molting on shell egg exterior, interior, and contents; microflora and Salmonella prevalence during a second production cycle. Poultry Sci. Suppl. 85: 100. (abst)

Santos, F., A. Santos, P. Ferket, and B. Sheldon. 2006. Influence of housing system, grain type and particle size on *Salmonella* colonization and shedding in broilers fed triticale- and corn-soybean meal diets. Poultry Sci. M45, p. 18-19. (abst)

### **C. Books and Book Chapters:**

Dawson, P.L., S. Mangalassary, and B.W. Sheldon, 2006. Thermal Processing of Poultry Products. *In: Thermal Food Processing: New Technologies and Quality Issues*. D. Sun, ed. CRC Press, Boca Raton, FL (Ch. 7, p. 197-233).

Zeidler, G., K.E. Anderson, and M. Samimi, Chapter 21, "Eggs and Egg Products", 2006 ASHRAE Handbook, Refrigeration, I-P and S-I Editions. M.S. Owen, Editor, American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE., Atlanta, GA 30329.

### **D. Manuscripts Approved:**

Payne, J.B., J.A. Osborne, P.K. Jenkins, and B.W. Sheldon. 2006. Modeling the growth and death kinetics of *Salmonella* in poultry litter as a function of pH and water activity. *Poultry Sci.*

#### **E. Symposia Presentations:**

B.W. Sheldon, 2006. Avian Influenza: What You Need To Know. Carolina Association for Food Protection Symposium. Clemson University, Clemson, SC, February 24, 2006.

#### **F. Proceedings:**

Ahlborn, G., and B.W. Sheldon. 2006. Potential for improving the safety of foods using an eggshell membrane waste product. In "Proceedings of the 2006 National Poultry Waste Management Symposium", Springdale, Arkansas, October 23-25, 2006 (on CD).

Li, X., J.B. Payne, F.B.O. Santos, K.E. Anderson, and B.W. Sheldon. 2005. Surveillance of *Salmonella* populations, prevalence and serotype diversity in layer feces as a function of production cycle and molting. In: Proc. Of the 2005 Animal Waste Management Symposium. The Development of Alternative Technologies for the Processing and Use of Animal Waste, Ed. G.B. Havenstein, Sheraton Imperial Hotel and Conference Center, Research Triangle Park, NC October 5-7, pp. 362-368.

Sheldon, B.W. 2006. Impact of laying hen Cycle and molting on the prevalence and populations of *Salmonella*. Proc. Midwest Poultry Federation Convention, Saint Paul River Centre, St. Paul, MN, March 21-23. In Egg Processing Session (on CD).

Sheldon, B.W., and X. Li. 2006. Reducing microbial cross-contamination in poultry processing plants using inhibitory conveyor belts. In "Proceedings of the EPC2006, XII European Poultry Conference", Verona, Italy, September 10-14, 2006 (on CD).

Sheldon, B.W., X. Li, J.B. Payne, F.B.O. Santos, and K.E. Anderson. 2006. Surveillance of *Salmonella* populations, prevalence and serotype diversity in layer feces as a function of production cycle and molting. In "Proceedings of the EPC2006, XII European Poultry Conference", Verona, Italy, September 10-14, 2006 (on CD).

#### **G. Popular and Trade Publications:**

Anderson, K. E. and A.G. Gernat. 2005. Does the use of Antibiotics in Poultry Production Pose a Risk to Human Health? North Carolina Poultry Newsletter, Vol. 2, No. 2, pp. 1-4. North Carolina Cooperative Extension Service, Summer 2005.

Sheldon, B.W., 2005. Controlling Pathogens. *Meat Processing* 44(8):67.

Sheldon, B.W., 2005. Enhancing Dark Meat Yields. *Meat Processing* 44(10):94.

Sheldon, B.W., 2005. Impact of Natural Versus Synthetic Pigments on Skin Color. *Meat Processing* 44(12):58.

Sheldon, B.W., 2006. No *Salmonella* Advantage. *Meat Processing* 45(2):56.

Sheldon, B.W., 2006. Sensory Attributes of Broiler Meat. *Meat Processing* 45(4):52.

Sheldon, B.W., 2006. Effective Microbial Controls. *Meat Processing* 45(6):97.

Sheldon, B.W., 2006. Lipid Oxidation: Control and Detection. *Meat Processing* 45(8):47.