90 Reducing egg-borne transmission of Salmonella Enteritidis in layer chickens by in-feed supplementation of caprylic acid. I. Upadhayya*1, A. Upadhay1, H.-B. Yin1, Z. Droczdowich1, M. Nair1, V. K. Bhattaram1, D. P. Karumathil1, S. Mooyottu1, M. I. Khan1, D. Schreiber1, A. Kollanoo-Johny2, M. J. Darre1, and K. Venkitanarayanan1, 1University of Connecticut, Storrs, CT; 2University of Minnesota, St. Paul, MN.

This study investigated the efficacy of feed supplemented with a GRAS-status, plant-derived compound, caprylic acid (CA) for reducing egg-borne transmission and organ colonization of Salmonella Enteritidis (SE) in 40-wk-old layer chickens. One hundred twenty Single Comb White Leghorn hens were randomly assigned to 6 treatments (n = 20/ treatment): a negative control (−ve SE, −ve CA), 2 compound controls (−ve SE, +ve 0.75% or 1% vol/wt CA), a positive control (+ve SE, −ve CA), a low dose treatment (+ve SE, +ve 0.75% CA) and a high dose treatment (+ve SE, +ve 1% CA). On d 0, birds were tested for any inherent Salmonella (n = 5/experiment), and CA was supplemented in the feed at the aforementioned levels for 64 d. On d 10, birds in the positive controls and low dose and high dose treatments were challenged with a 5-strain mixture of SE (10 log10 cfu/bird) by crop gavage. After 4 d of challenge, eggs were collected and examined for SE in the yolk and on the shell daily until the end of the trial. On d 64, 10 birds from each treatment were killed to determine SE presence in the cecum, liver, and oviduct. Caprylic acid at 0.75% reduced SE on shell by ~21% and in yolk by 24%, whereas supplementation of 1% CA reduced SE by ~44% on shell and ~32% in yolk. Additionally, CA at both concentrations reduced SE in cecum, liver and oviduct (P < 0.05) by ~30 to 40% compared with control birds. No significant differences in egg production were observed among the different treatment groups (P > 0.05). The results suggest that CA could potentially be used as a feed additive to reduce egg-borne transmission of SE in layer chickens.

Key Words: Salmonella, egg, chicken, caprylic acid

91 Intracloacal inoculation, an effective screening method for determining the efficacy of bacterial isolates against Campylobacter colonization in chickens. K. Arsi*1, A. M. Donoghue2, A. Woo-Ming1, H. R. Arambel1, S. Shrestha1, P. J. Blore1, K. Venkitanarayanan1, and D. J. Donoghue1, 1University of Arkansas, Fayetteville, AR, 2Poultry Production and Product Safety Research Unit, USDA-ARS, Fayetteville, AR, 3University of Connecticut, Storrs, CT.

Campylobacter, a leading cause of foodborne illness, is often associated with consumption of contaminated poultry products. Strategies to eliminate Campylobacter from poultry have had limited success. One strategy to reduce Campylobacter colonization in poultry is by the use of oral probiotics. Unfortunately, oral probiotics can produce variable results, possibly due to destruction in the acidic environment of stomach. Encapsulation of isolates may overcome this problem but there is no assurance these isolates will have efficacy in the lower GI tract. Therefore, screening candidate isolates by directly placing them in the lower intestinal tract via cloacal inoculation may eliminate the time and expense of encapsulating ineffective isolates. Thus, the purpose of this study was to collect bacterial isolates with anti-Campylobacter activity in vitro and evaluate their efficacy in vivo upon either oral or intracloacal administration. Sixty-seven bacterial isolates (all Bacillus spp.) with GRAS (Generally Regarded as Safe) status were isolated from healthy birds and evaluated for efficacy against C. jejuni, in vitro. The isolates were identified and subjected to motility enhancement, as our previous studies demonstrated that motility enhanced isolates can reduce Campylobacter colonization in poultry more effectively than control isolates. Ten GRAS isolates demonstrating in vitro anti-Campylobacter properties and enhanced motility were evaluated after either oral or intracloacal inoculation into day of hatch chicks (n = 10 birds/isolate). When dosed orally, only one isolate showed a 1 log reduction in cecal Campylobacter counts in 14-d-old birds. When these isolates were administered intracloacally, 5 of these isolates produced up to a 3 log reduction in Campylobacter counts compared with controls (4 vs. 7 log cfu/g, P < 0.05). These results support the strategy of evaluating the efficacy of potential probiotic isolates via cloacal inoculation before undergoing the effort of protecting isolates (e.g., encapsulation) for oral administration.

Key Words: Campylobacter, probiotic, GRAS, chicken, intracloacal

92 Efficacy of the natural compound, β-resorcylic acid, against Campylobacter colonization in poultry. B. R. Wagle*1, A. M. Donoghue1, K. Arsi1, A. Woo-Ming1, H. R. Arambel1, S. Shrestha1, P. J. Blore1, K. Venkitanarayanan1, and D. J. Donoghue1, 1University of Arkansas, Fayetteville, AR, 2Poultry Production and Product Safety Research Unit, USDA-ARS, Fayetteville, AR, 3University of Connecticut, Storrs, CT.

Campylobacteriosis is one of the leading foodborne illnesses in the United States and is associated with the consumption of poultry and poultry products. Reducing Campylobacter colonization in poultry will reduce the burden of this disease in humans. Unfortunately, most strategies to reduce enteric colonization of Campylobacter have either not been successful or produced inconsistent results. One potential control strategy is the use of phytophenolic compound, β-resorcylic acid (BR), which has antibacterial activity against another foodborne pathogen, Salmonella. However, its efficacy to control Campylobacter in poultry has not been evaluated. Preliminary studies in our laboratory demonstrated that BR kills C. jejuni in vitro. Therefore, the objective of this study was to evaluate if β-resorcylic acid would reduce enteric Campylobacter colonization in birds. To accomplish this, day of hatch chicks were fed 1 of 5 treatments (0, 0.25, 0.5, 1 or 2% BR) in the first trial, whereas a second trial was conducted including 2 additional doses of 0.75% and 1.5% BR, with a total of 7 treatments (n = 10 chicks/dose). Birds were challenged with 4 wild strains of C. jejuni (approx. 106 cfu/mL) on d 5 and cecal samples were collected on d 14 and enumerated for Campylobacter. Data were logarithmically transformed and treatment means were partitioned by LSMEANS analysis (P < 0.05). Campylobacter counts were reduced by 1.4 log cfu/g for the 2% dose or 4.2 or 2.8 log cfu/g for the 0.5% and 1% BR doses for the first or second experiment, respectively. Increasing the dose of BR in the feed to enhance the efficacy of this compound would not be practical because feed consumption and body weight gain were reduced with the higher doses (1.5% and 2% BR). These results suggest β-resorcylic acid has the potential to reduce enteric colonization of Campylobacter but further explorations with encapsulation or combination of phytophenolic compounds are warranted to ensure consistent efficacy. Funded in part by the USDA-NIFA-OREI 2011–01955.

Key Words: Campylobacter jejuni, β-resorcylic acid, in vivo, control, chicken

Campylobacter is a major cause of foodborne illness in humans worldwide. Poultry is a major reservoir of this pathogen and consumption of poultry and poultry products is reported to be the primary cause of Campylobacter infections in humans. Unfortunately, efforts to reduce Campylobacter in preharvest poultry have been met with limited success. Preliminary studies with the natural compound, chitosan, demonstrate its ability to kill Campylobacter, in vitro. Because chitosan’s antimicrobial properties may vary depending upon its molecular weight of the chitosan, 3 molecular weight chitosans were tested in the feed. These included a low molecular weight (50–190 kDa), medium molecular weight (190–310 kDa), and high molecular weight (400–600 kDa) chitosan. Day of hatch broiler chicks were randomly divided into 10 treatments groups (n = 10 birds/treatment). Treatment groups consisted of 0.25%, 0.5%, and 1% (wt./wt.) of each molecular weight of chitosan (low, medium and high), as well as positive control (no chitosan); treated feed was provided throughout the entire trial. Birds were orally challenged with 4 different Campylobacter strains on d 6 and cecal samples were collected for Campylobacter enumeration on d 15. Three replicate trials were conducted. Campylobacter colonies counted were logarithmically transformed (log 10 cfu/g) and treatment means were partitioned by LSMEANS analysis (P < 0.05). Significant reductions of Campylobacter were observed with 0.5% medium molecular weight chitosan in each of the 3 replicate trials with 1 to 3 log reduction in these groups compared with controls. These results support the application of this natural compound to feed to help reduce enteric Campylobacter colonization in chickens. Funded in part by the USDA-NIFA-OREI 2011–01955.

Key Words: Campylobacter jejuni, chitosan, in vitro, broiler chicken

94 Effect of two Bacillus subtilis strains on production and Salmonella colonization in male broilers. A. N. Frazier*, J. Krehling, L. Olivia, K. English, and K. Macklin, Auburn University, Auburn, AL.

With the growing concern about antibiotic resistant bacteria in commercial poultry, there is need for a new approach. Growing evidence indicates a direct-fed microbial (DFM) diet can help reduce Salmonella in the chicken GI tract. A commonly used probiotic is the bacterium Bacillus subtilis (BaS). An experiment was conducted to test the effects of a DFM diet with 2 BaS strains (AB01 and AP71) on broiler production and the effects of the diet against Salmonella Enteritidis (SE) colonization. Six hundred day-old chicks were placed into 24 pens (25 chicks/pen) and were randomly assigned one of 4 treatments. The 4 treatments consisted of a BaS treated and challenged group (trt1); a BaS treated and non-challenged group (trt2); a non-BaS treated and challenged group (trt3); and a non-BaS treated and non-challenged group (trt4). From d 0 to d 14 the chicks were fed a starter ration that had no DFM added or was treated with 1.5 × 107 cfu/g of BaS. At d 14, 2 strips of challenge pens were inoculated with SE and BaS in trt1 and trt3 were fed a BaS treated grower (1.8 × 107 cfu/g). Trt2 and trt4 pens were placed on non-treated grower. At d 28, trt1 and trt3 pens were placed on a finisher containing BaS (1.8 × 107 cfu/g), while trt2 and trt4 pens were fed a standard finisher ration. Liver, spleen and ceca samples were taken from 5 birds per pen via necropsy at d 14, 28 and 35. Bird and feed weights were also assessed. Feed conversion, anaerobic and aerobic bacteria counts, and SE counts from ceca, liver and spleen samples were analyzed using GLM with means separated via Tukey’s HSD. Analysis of the data revealed no significant difference in feed conversion (P > 0.05) or in anaerobic or aerobic bacteria for all sampling dates. Day 28 showed a significant increase in Salmonella in ceca, spleen and liver samples. At d 35 there was a significant difference between trt3 and trt2. After analysis of all data, the AB01-AP71 BaS DFM diet had no effect on broiler production or Salmonella colonization.

Key Words: probiotic, Salmonella, DFM, antibiotic resistance

95 Evaluation of transmission of Salmonella and Campylobacter through artificial insemination of breeder turkeys to eggs and offspring. M. D. Crespo Rodriguez*, J. L. Grimes, S. Kathariou, N. A. Cox, R. J. Buhr, and D. P. Smith, North Carolina State University, Raleigh, NC, 2USDA-ARS-RRC, Athens, GA.

Salmonella and Campylobacter are pathogens of public health concern associated with poultry products. Preharvest control in breeder flocks and their offspring is crucial to reduce the transmission of these bacteria through the food chain. However, the direct vertical transmission of these organisms through fertile turkey eggs to offspring has not been demonstrated. The objective of this study was to detect transmission of Campylobacter and Salmonella in the offspring of turkeys. Eighty breeder hens were inoculated with a nalidixic acid-resistant Salmonella Enteritidis and a gentamicin-resistant strain of C. coli via semen through artificial insemination. A control flock (20 hens) was inseminated with semen without the pathogens. Eggs (675) from inoculated hens (IH) and 190 from control hens (CH) were hatched separately. At day of hatch, hatchery pads with fecal droppings from both groups were analyzed for both bacteria. Pouls from IH (496) and CH (124) were placed in separate areas of a growout house and pooled fecal samples from each group were analyzed weekly. At d 8 and 36 intestinal tract samples from 10 pouls of each group were analyzed. Ceca from 20 pouls per group were tested at 16 weeks. Reproductive tract (RT) from 20 breeder hens at 65 weeks and semen from tombs were also analyzed. Salmonella and Campylobacter were not isolated from hatchery pads or fecal droppings at day of hatch. Marker strains were not isolated from any of the fecal or intestinal samples from pouls from IH. Salmonella Enteritidis (marker) was found in RT of IH (30%), and Campylobacter (unrelated to the inoculated strains) was isolated from RT in IH and CH (15%). Unrelated strains of both pathogens were isolated from fecal and intestinal samples. In conclusion, no evidence of vertical transmission of these pathogens through artificial insemination was demonstrated. However, marker Salmonella was found in RT of IH and several unrelated strains of Campylobacter were also isolated from semen (100%) and RT of hens, indicating a potential route of transmission of these pathogens to the offspring.

Key Words: Salmonella, Campylobacter, turkey, breeder, offspring


In 2011, the Food Safety and Inspection Service (FSIS) initiated new performance standards for the reduction of Campylobacter on raw retail poultry carcasses. Epidemiological evidence has indicated that Campy-
lobacter infection in humans is related to consumption of contaminated poultry products. Many strategies are currently being investigated to reduce Campylobacter counts on commercially produced poultry. Use of natural compounds, including essential oils and saturated fatty acids, with Generally Recognized as Safe (GRAS) status is a practical strategy for reduction of Campylobacter as these compounds can be immediately implemented into a pathogen reduction regimen by poultry processors. Chicken thigh skin, obtained from a retail store, was cut into 2-g samples and inoculated with approximately 1 × 10^6 cfu/mL of Campylobacter jejuni, which was then allowed to adhere for 30 min. In replicate trials, inoculated skin was dipped into a solution of either trans-cinnamaldehyde or sodium octanoate at a concentration of 0, 0.5, 1, or 2% (vol./vol.) for 30 s, and then given an additional 2 min of contact time before being serially diluted (1:10) in Butterfield’s Phosphate Diluent and plated onto Camp Line Agar (n = 10/dose). Colony counts were transformed to log cfu per gram for statistical analysis. The data were analyzed by ANOVA using SAS software and expressed as least squares means with differences considered significant at P < 0.05. Concentrations of 0.5%, 1% or 2% trans-cinnamaldehyde did not produce a significant reduction in Campylobacter on chicken skin. The lowest concentration (0.5%) of sodium octanoate failed to produce a statistically significant reduction as compared with the control (0%). However, higher concentrations, 1% or 2% sodium octanoate demonstrated a significant reduction in Campylobacter counts, of approximately 1 log compared with the control. 

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**Key Words:** food safety, Campylobacter, poultry processing, natural compound

97  **Evaluation of compatibility of Salmonella lytic bacteriophage with different antimicrobials and their combinations on reduction of Salmonella in vitro and on chicken breast fillets.** A. T. Sukumaran* and C. S. Sharma, Mississippi State University, Mississippi State, MS.

The objectives of this study were to determine the survivability of Salmonella bacteriophage in antimicrobials used during poultry processing and to determine the efficacy of bacteriophage in combination with compatible antimicrobials in reducing Salmonella in vitro and on chicken breast fillets. Bacteriophage preparation (10^9 pfu/mL) was mixed with cetylpyridinium chloride (CPC, 0.4, 0.6, and 1%), lauric arginate ester (LAE, 200 and 5,000 ppm) and peracetic acid (PAA, 30, 40, 50, 100, 200, and 700 ppm) and stored at 4°C for 24 h. The number of surviving bacteriophages was determined by soft agar overlay technique. There was no effect (P > 0.05) of all tested concentrations of CPC and LAE on the survival of bacteriophage as compared with the control (bacteriophage + DI water) whereas bacteriophage was not able to survive in PAA solutions (100, 200, and 700 ppm). However, up to 6.5 log cfu/mL were recovered in low strength PAA solutions (30, 40, and 50 ppm) compared with control (9.3 log cfu/mL). The application of phage (10^10 multiplicity of infection (MOI)) in combination with 0.6% CPC and 200 ppm LAE was examined for reduction of Salmonella (Salmonella Typhimurium, Salmonella Heidelberg and Salmonella Enteritidis) in 0.1% peptone water at 4°C for 24 h and on chicken breast fillets inoculated with cocktail of the 3 serotypes up to 7 d. Irrespective of the serotypes, antimicrobial, storage time and MOI of phage, all treatments resulted in complete inactivation of Salmonella in vitro compared with the control (6 log cfu/mL). On chicken breast fillets, all the combinations of phage and antimicrobials resulted in significant (P < 0.05) reductions of Salmonella throughout d7 of storage with reductions ranging from 0.85 log cfu/g to 2.15 log cfu/g compared with positive controls (3.2–3.6 log cfu/g). Among all treatments, the combination of phage (10^10 MOI) and CPC showed the highest reductions of 1.1, 2.15, and 1.4 log cfu/g on d 0, 1, and 7, respectively. In conclusion, phage preparation was able to survive in CPC and LAE and their combination was effective in reducing Salmonella on chicken breast fillets.

**Key Words:** Salmonella, cetylpyridinium chloride, lauric arginate, bacteriophage

98  **Effect of acid adaptation on heat treatment of Salmonella Heidelberg in ground turkey.** J. M. Smith*1 and M. Singh2,1Auburn University, Auburn, AL, 2Purdue University, West Lafayette, IN.

Salmonella enterica serovar Heidelberg is the leading cause of human Salmonellosis, and ground poultry products are increasingly implicated in such outbreaks. In this study, the thermal tolerance of acid-adapted and non-adapted Salmonella Heidelberg was evaluated in ground turkey meat stored under refrigeration (4°C). Salmonella Heidelberg was adapted to acidic conditions by growing in tryptic soy broth supplemented with 1% glucose at 37°C to a final pH of 4.70, whereas the non-adapted culture was grown in tryptic soy broth with a final pH of approximately 6.10. Irradiated ground turkey was inoculated with either acid-adapted or non-adapted Salmonella Heidelberg, and 2-g portions were packaged in plastic pouches and heat sealed for storage at 4°C. Samples were subjected to heat treatment of 62°C and 65°C in a circulating water bath for 180 s after storage for 0, 3, 6, 9, and 12 d and subsequently plated onto plate count agar to determine survival populations. Acid-adapted Salmonella Heidelberg displayed more sensitivity to both 62°C and 65°C heat treatment than non-adapted Salmonella Heidelberg during the course of exposure time. The storage period resulted in lower (P < 0.05) survival populations of acid-adapted Salmonella Heidelberg over time even though recovery of Salmonella Heidelberg from inoculated meat samples was constant [~6.50 log10 cfu/g] over the storage period. Survival populations of 0.70 log10 cfu/g at 180 s on d 0 were observed, whereas the survival populations were below detection limit after 180 s on subsequent days of storage. This suggests that acid-adapted Salmonella Heidelberg has the ability to survive in ground meat. However, its susceptibility to thermal treatments is higher than its non-adapted equivalent in ground turkey over time.

**Key Words:** Salmonella Heidelberg, acid-adaptation, ground turkey

99  **Antimicrobial efficacy of carvacrol against Salmonella, Campylobacter, and lactic acid bacteria on turkey breast cutlets stored under modified-atmosphere packaging.** D. V. T. Nair* and C. S. Sharma, Mississippi State University, Mississippi State, MS.

The objective of this study was to determine the combined efficacy of carvacrol and modified-atmosphere packaging (MAP) in reducing Salmonella, Campylobacter and lactic acid bacteria on turkey breast cutlets stored at 4°C. Turkey breast cutlets were inoculated with a 3-strain cocktail of Salmonella (Salmonella Enteritidis, Salmonella Heidelberg, and Salmonella Typhimurium) and 2-strain cocktail of Campylobacter jejuni followed by dipping in 0.25, 0.5, and 1% carvacol for 30 s and stored under MAP (~95% CO2 and 5% O2) at 4°C. Positive (inoculated, not treated with carvacol and stored under aerobic and modified atmosphere) controls were also included in the study. Samples were analyzed on d 1, 3, and 7 of storage for the survivability of Salmonella and Campylobacter jejuni. The efficacy of carvacol and MAP on the growth of lactic acid bacteria (LAB) was determined by dipping non-inoculated cutlets in 0.25, 0.5, and 1% carvacol for 30s and storing the samples under MAP at 4°C. The LAB counts were taken on d 0, 7, 14, and 21 of storage.
The combined application of carvacrol and MAP caused significant ($P < 0.05$) reductions (1.0 to 2.0 log cfu/g) of *Salmonella* and *Campylobacter* on turkey breast cutlets on each day of analysis. High CO$_2$ packaging resulted in significant ($P < 0.05$) inhibitory effect on the growth of LAB after 7 d of storage of turkey cutlets compared with aerobic packaging. On d 7, 14, and 21 compared with aerobic packaging, carvacrol at all concentrations with MAP caused significant reductions ($P < 0.05$) of LAB (1.7–2.5 log cfu/g). There was no difference in the meat color among treatments and controls ($P > 0.05$) except the increased paleness of meat ($P < 0.05$) observed for the combination of 1% carvacrol and MAP on d 21. In conclusion, carvacrol was effective in reducing *Salmonella*, *C. jejuni*, and lactic acid bacteria on turkey breast cutlets with concentrations as low as 0.25% when used in combination with high CO$_2$ packaging.

**Key Words:** *Salmonella*, *Campylobacter*, lactic acid bacteria, carvacrol, modified-atmosphere packaging

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**100 The effects of sorghum phenolic compounds used as lipid antioxidants in chicken nuggets.** G. Casco*1, L. C. Cavitt2, G. Veluz1, R. Miller1, and C. Z. Alvarado1, 1Texas A&M University, College Station, TX, 2Tyson Foods Inc., Springdale, AR, 3SGS Pte Ltd., Singapore, Malaysia.

Phenolic compounds from sorghum and spices provide antioxidant properties in foods. The objective of this study was to evaluate the effects of adding sumac 0.25% (S) and black tannins 0.25% (BT), sorghum-based antioxidants, and compare them to a rosemary essential oil control (R, 0.20%) in fully cooked chicken nuggets. In 3 trials, the nuggets (breast meat 45%, thigh meat 45%, water, NaCl 0.725%, and antioxidant) were manufactured according to industry practices; batter/breaded to 28% pickup, par-fried (188°C, 45 s), fully cooked (oven 196°C, 40% steam), and then individually frozen in a spiral freezer. Yields ($n = 18$) were determined on battered/breaded, par-fried, cooked, and frozen nuggets. Color ($n = 15$) L*a*b* scale was determined on the meat block using a Minolta colorimeter at 0, 2, 4, and 6 mo (OC). Lipid oxidation (MDA/kg) was determined from a ground composite sample of 3 nuggets in duplicate weekly for 12 wk in accelerated frozen storage conditions. A triangle test of the combined trials was performed on frozen samples at 0, 2, 4, and 6 mo from frozen storage ($n = 37, 40, 50$, and 50; respectively at $α = 0.05$). Results indicated that S had significantly lower par-fried yields to R, but did not differ in cooked yields. The BT had lower ($P < 0.05$) cooked yields to both R and S. Color results indicated R were the whitest nuggets ($P < 0.05$) followed by S and then the BT, which were the darkest nuggets ($P < 0.05$) on each sample time. Nuggets containing S and BT inhibited oxidation at the same ($P > 0.05$) level as R nuggets over time. Moreover, consumer sensory testing showed that panelists were able to detect differences ($P < 0.05$) between BT and R on mo 2, 4, and 6, whereas S nuggets were different at mo 0 and 4. Overall, sumac and black tannins from sorghum can reduce lipid oxidation as well as rosemary without having negative effects on yields; however, consumers were able to detect the presence of these compounds.

**Key Words:** tannin, phenol, antioxidant, chicken nuggets, sorghum

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**101 Sodium reduction in processed meats: Cold-batter mincing of hot-boned and crust-freeze-air-chilled turkey breast reduced sodium content in protein gels.** P. Singh*1, M. M. Lopez1, H. C. Lee1, T. Sansawat1, K. B. Chin2, and I. Kang3, 1Michigan State University, East Lansing, MI, 2Chonnam National University, Gwangju, South Korea.

This research was aimed to evaluate sodium reduction in the protein gels that were prepared with turkey breasts after hot boning (HB), quarter sectioning (1/4), crust-freeze air chilling (CFAC), and cold temperature mincing. For each of 4 replications, 36 turkeys were slaughtered and eviscerated. Half of the carcasses were randomly assigned to water immersion chilling (WIC) for chill-boning (CB), whereas the remaining were immediately IB and quarter sectioned/crust-freezing air chilled (1/4CFAC) in a freezing room (–12°C/1.0 m/s). After deboning, CB fillets were conventionally minced, whereas HB-1/4CFAC fillets were cold minced up to 27 min with 1 or 2% salt. Data were evaluated by one-way ANOVA. A post hoc analysis was performed using Duncan’s multiple range test to evaluate difference among treatments at $P < 0.05$.

From the beginning of mincing, the batter temperatures of HB-1/4CFAC were lower by 9.6°C or more than those of CB batters up to 12 and 21 min for 2 and 1% salts, respectively. During mincing, the batter pH of HB-1/4CFAC rapidly decreased to 5.84 and 5.77 for the 2 and 1% salts, respectively, at 12 min and showed no differences from the CB batters thereafter, except the 1%salt HB-1/4CFAC batter showing the lowest pH after 15 min of mincing. The pattern of pH was not changed when the batters were stored overnight. The protein solubility of 2% salt HB-1/4CFAC fillets was higher by 18.7, 11.4, 19.0 and 19.3% than those of CB fillets at 9, 12, 18 and 24 min, respectively. Similarly, the protein solubility of 1% salt HB-1/4CFAC fillets was higher by 10.3% or more than those of CB fillets after 12 min mincing. Stress values of 2% salt HB-1/4CFAC gels were significantly higher than those of 1 and 2% salt CB gels, with intermediate values for 1% salt HB-1/4CFAC gels. In scanning electron microscope image, pre-rigor batter appears to have more open space, less protein aggregation, and more protein-coated fat particles than those of post-rigor batters. Combination of HB-1/4CFAC and cold-batter-mincing technologies appeared to improve protein functionality and sodium reduction capacity.

**Key Words:** sodium reduction, hot-boning, crust-freezing, cold mincing, protein functionality