Evaluation of a High ph Solution as an Alternative to Phosphate for Meat Enhancement

Claudia A. Cerruto-Noya, Deborah VanOverbeke and Christina A. Mireles DeWitt

Story in Brief

USDA Select, paired beef strip loins aged for 2 d were enhanced to 110% of original weight with either a high pH solution containing 3.6% sodium chloride, 1% Herbalox seasoning and adjusted to pH 10 with ammonium hydroxide (~.1%, FFC grade) or a phosphate based solution (pH 8.45) prepared using 3.6% sodium chloride, 1% Herbalox seasoning, and 4.5% sodium tripolyphosphate. In order to evaluate storage quality under retail conditions, sample pH, proximate analysis, microbial growth, lipid oxidation, color score, purge loss, cook loss, Warner-Bratzler shear force and sensory panel were measured. Composition of enhanced steaks differed in moisture, ash, and protein content. Phosphate enhanced steaks were about 2% lower in protein content. This was attributed to the higher purge observed in alkaline enhanced steaks. Overall, it was observed that phosphate enhanced steaks performed better than alkaline treatment in all quality parameters measured except for controlling microbial growth. The alkaline treatment had significantly lower ($p<.05$) aerobic and anaerobic plate counts.

Keywords: Ammonium Hydroxide, Enhancement, Meat, pH, Phosphate

Introduction

It is important for the beef industry to meet consumer and retail market demands. These include an ever increasing desire for improving low value cuts and carcass value. As a result, value-added approaches such as novel fabrication techniques have been used to satisfy consumer demands (Robbins et al., 2003). Also, solution enhancement has been widely used to improve palatability in order to increase the acceptance of lower value cuts of meat (Morgan et al., 1991). Thus, currently enhanced meat products are extensively produced by the meat industry. There are many advantages to using meat enhancers such as improving tenderness, moisture, flavor, extended shelf life, food safety, appearance, new product development, consumer convenience, reducing rancidity, and increasing profitability (Foote et al., 2004). In most cases phosphates, salt, nitrites, antioxidants, sugar, and flavorings are added or injected into meats as "enhancers" to achieve these advantages. However, at present the extensive use of phosphates presents two concerns for the industry. Phosphates are "chemical additives" and therefore can be perceived by the consumer as not "natural" to the product. Consumers are demanding "natural" beef products without chemical additives (Perez-Rocha and Varsi, 2003). In addition, phosphates are a health concern for certain segments of society. People suffering from kidney disease, impaired renal function or perfusion, dehydration, or uncorrected electrolyte abnormalities must avoid foods containing high levels of phosphates (Block et al., 1998; Goodman et al., 2004; Ibels et al., 1978; Tonelli et al., 2005; Van and Mireles DeWitt, 2007). Consequently, it is important for the meat industry to find alternatives to decrease the utilization of phosphates as enhancers in order to better serve all consumers. Therefore, the objective of this study was to compare

physical, chemical and microbiological affects of beef subprimal strip loins injected with a high pH-enhancement solution to those injected with a commercially based phosphate enhancement.

Materials and Methods

Sample Collection. Paired beef strip loins aged for 2 d were identified and collected randomly from USDA Select quality grade at a beef fabrication facility. Strip loins were labeled, vacuum packaged, refrigerated, transported, and stored overnight at 4ºC.

Sample Enhancement. Initial weight (green weight) of each subprimal was recorded the next day. Each paired subprimal was randomly injected with either the phosphate or the alkaline based solution at 4ºC using a stitch pump enhancer calibrated to inject at 110% of the recorded green weight.

High pH Solution Injection. The alkaline solution was an aqueous solution containing 1% Herbalox seasoning type HTW (Kalsec, Kalamazoo, Mich., U.S.A.) and 3.6% sodium chloride (w/w) adjusted to pH 10 using food grade ~.1% ammonium hydroxide (Fisher Scientific, Fair Lawn, New Jersey, U.S.A.).

Phosphate Solution. The phosphate solution was prepared with 4.5% sodium tripolyphosphate (BK Giulini Corporation, Germany), 3.6% sodium chloride, and 1% Herbalox seasoning type HTW.

Fabrication of Subprimals into Steaks. After injection, strip loins were held for 30 min at 4ºC. To equilibrate, the weight of each strip loin was recorded prior to fabrication into 2.54 cm steaks using a standard band-saw. Individual steak weights were recorded. Steaks were placed into plastic trays with absorbent pads and packaged under a high-oxygen (80% oxygen, 20% carbon dioxide) modified atmosphere packing (MAP) using a MAP machine (G. Mondini S.p.a., Type CV/VG-S, Brescia, Italy). Packaged steaks were placed in dark storage at 4ºC for 4 d in order to simulate transportation to retail stores. After 4 d dark storage, steaks were placed in a retail case at 4ºC under cool white fluorescent lights, with a continuous intensity of 75 foot-candles for 14 d.

Day 5 to 19 Sampling. Three steaks were randomly selected from each treatment on days 5 (d 0 retail display), 12 (d 7 retail display), and 19 (d 14 retail display). One steak was used to measure retail case purge, cook loss, HunterLab color and shear force analysis. A second steak was used for retail case purge, cook loss, HunterLab color and sensory analysis. The third steak was selected for anaerobic and aerobic plate count, proximate analysis, and 2-thiobarbituric acid reactive substances (TBARs) analysis.

Proximate Analysis. Steaks were sampled first for microbiological analysis and frozen. Steaks were thawed and sampled for TBARs analysis. The remainder of the steak was powdered using liquid nitrogen and a frozen waring blender in a cold room. Powdered samples were measured for moisture (AOAC, method number 95.46), crude fat (AOAC, method number 960.39), ash (AOAC, method number 920.153), and protein (AOAC, method number 928.08).

Microbiological Analysis. Aerobic and anaerobic plate counts were conducted in accordance with the official methods of analysis of AOAC international by FoodProtech® (Stillwater, Okla., U.S.A.).

Lipid Oxidation. Samples from day 5, 12 and 19 were packaged in Whirl-Pak® bags, and frozen at −20ºC until analyzed. A 10 g sample was taken from the surface of the steak and analyzed according to a modified method based on Buege and Aust (1978). Results were reported as mg malondialdehyde (MDA) equivalents per kilogram of fresh meat.

Color Score. Steaks were color scored according to the Guidelines for Meat Color Evaluation (AMSA, 1991) by a trained panel using a scale of 1 to 7. Twice a day (morning and night) six panelists scored steaks for lean color, fat color, percent discoloration, and overall acceptability.

HunterLab Color Score. Quantitative evaluation of color was measured using a MiniScanTM XE Plus (HunterLab, Reston, VA). The instrument was calibrated using a white calibration tile. A reading was taken on each steak, avoiding any seam fat, prior to cooking. For each treatment, two steaks were measured from each subprimal (n=10) each day. Lightness (L* value of 100 is white), redness (positive a* value), and yellowness (positive b* value) values were measured on d 5, 12, and 19.

Purge Analysis. The amount of liquid lost during the storage of the steak was recorded by subtracting stored steak weight from initial steak weight.

$$\%\ \text{purge} = \frac{(\text{weight}_{\text{priorpakage}}) - (\text{weight}_{\text{afterstorage}})}{(\text{weight}_{\text{priorpakage}})} \text{ X } 100$$

Cook Loss. Steaks were cooked as outlined in the section for shear force. The amount of moisture lost through cooking steaks was calculated:

$$\text{Cookloss} = \frac{(\text{weight}_{\text{priorcook}}) - (\text{weight}_{\text{cooked}})}{(\text{weight}_{\text{priorcook}})} \text{ X } 100$$

Shear Force. After cooking steaks up to 70ºC internal temperature, shear force was measured according to Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Fresh Meat (AMSA, 1995). Six samples from each steak were tested and then averaged.

Sensory Panel. Sensory evaluation was performed by an experienced group of panelist (n=20) following the methodology in the Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat (AMSA, 1995). Each panelist was asked to evaluate two cooked steak cubes of 2.54 cm for tenderness, juiciness, connective tissue, and overall acceptability. Samples from animal paired strip loins were evaluated six times by six different panelists.

Statistical Analysis. Data were analyzed using Proc Mixed of SAS (SAS Inst. Inc., Cary, N.C., U.S.A.) as a 2 x 3 factorial in a randomized block design using $\alpha = .05$. Sample ID was the random variable; treatment and day were fixed variables. When appropriate, means were separated using least significant difference (LSD).

Results and Discussion

Enhancement. The target percent pump weight was 110% of the initial weight for the enhancement solutions. The average for the alkaline enhanced subprimals was 11.50±2.09% while for phosphate enhanced subprimals was 13.58±1.61%.

Sample pH. There was a significant difference between treatments, day and day*treatment interaction (P<.05) for pH analysis. The alkaline treatment resulted in a lower pH than the phosphate treatment (overall mean 5.73±.10 and 5.99±.12, respectively). Higher pH of meat is important with respect to maintaining color, holding water, and improving tenderness. As can be seen, even though final meat pH is only .3 lower in the alkaline than the phosphate treated samples, this difference significantly affects many of quality parameters.

Proximate Analysis. Proximate analysis was performed for d 5 (0 d retail display), 12 (7 d retail display), and 19 (14 d retail display). Data showed significant differences between treatments for moisture, protein, and ash content (P<.05). However, no significant differences in fat content between treatments were found. Over the course of 19 days, steaks enhanced with a phosphate based solution were higher in moisture and ash content than alkaline enhanced steaks (moisture: 75.27 ± 1.40% against 74.54 ± 1.39%, respectively; ash: 2.08 ± 0.14% in contrast to 1.41 ± 0.25%, respectively). The higher moisture content was likely a result of a higher water holding capacity due to a higher final pH in steaks enhanced with a phosphate based solution. In addition, steaks enhanced with alkaline solution had higher protein content (20.18 ± 0.80%) than steaks enhanced with phosphate (18.64 ± 0.65%). The higher percent of protein in alkaline enhanced steaks was attributed to a higher purge loss.

Table 1. Proximate analysis of injected strip loin steaks enhanced with alkaline solution or phosphate based solution stratified by days and treatments.

Treatment	% Moisture	% Fat [c]	% Ash	%Protein
Alkaline	74.54[a]±1.40	4.65±1.45	1.41[a]±.08	20.18[a]±.80
Phosphate	75.27[b]±1.41	4.61±1.53	2.08[b]±.19	18.64[b]±.65

[c] Treatment and day effects were not significant ($P>.05$).

[a, b] Means appearing in the same column with different superscripts are significantly different ($P<.05$).

Microbiological Analysis. For aerobic and anaerobic microbial growth, a significant difference was observed between treatments, time and their interaction (P<.05).

Microbial populations were significantly lower in steaks treated with alkaline (Figure 1). Microbial populations of alkaline steaks at the end of the study (14 d retail display) were essentially the same as the phosphate injected steaks at 0 d retail display (d 5 of study).

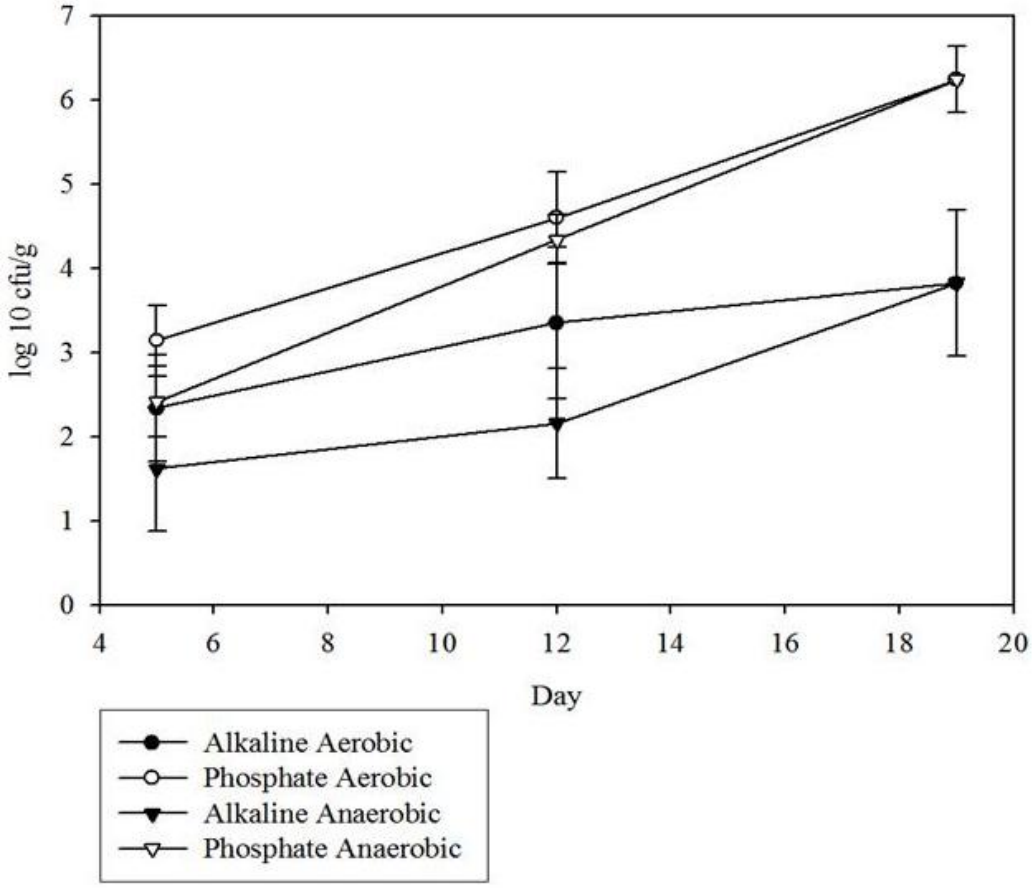

Figure 1. Aerobic and anaerobic microbial populations of strip loin steaks after injection to 110% green weight with alkaline solution or phosphate based solution.

Lipid Oxidation. There was a significant difference in TBARs content (P<.05) with samples injected with phosphate being lower than alkaline (Figure 2). Phosphate enhanced steaks had a mean of .10±.22mg maldonaldehyde (MDA) per kg of fresh meat while the mean for alkaline enhanced steaks was .77±.44 mg MDA/kg of fresh meat. Over time, lipid oxidation increased (P<.05).

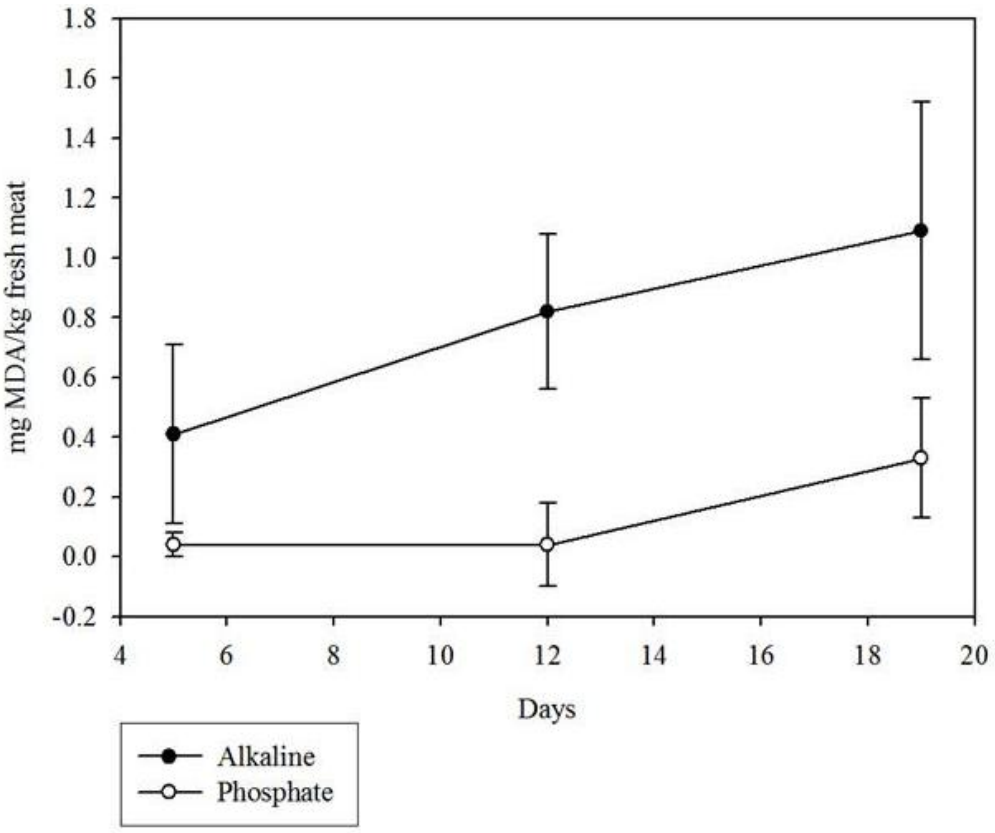

Figure 2. Lipid oxidation of strip loin steaks after injection to 110% green weight with alkaline solution or phosphate based solution.

Purge Analysis. There was a significant difference between treatments (P<.05). Purge was 3.5% less for phosphate enhanced steaks (2.09±2.29%) than alkaline (5.40±.97%). Purge also increased over time (P<.05). However, the day by treatment interaction was not significant (P=.62).

Cook Loss. Phosphate treatments lost less water (P<.05) during cooking than alkaline treatments (mean 20.53±3.06 and 26.69±2.17, respectively). However, day and the day by treatment interaction did not have an effect on cook loss (P=.25 and P=.83, respectively).

Shear Force. Over 19 days of study, phosphate enhanced steaks were significantly (P<.05) more tender than alkaline enhanced steaks (2.59±.46 against 3.37±.90, respectively; Table 7). Day and day by treatment interaction did not affect tenderness (P=.75 and P=.62, respectively).

Subjective Color Score. Phosphate enhanced steaks performed better with respect to lean color than the alkaline treatment (P<.05) having an overall mean of 4.97±.10 and 4.29±.91, respectively. Fat color scores were also significantly different (P<.05) between treatments. The phosphate treatment had an average of 6.20 ± 1.19 and alkaline treatment 5.93±1.30. Also, steak discoloration was higher (P<.05; Figure 3) in phosphate

(5.77±1.14) than alkaline (5.21±1.11) enhanced steaks. Overall acceptability (Figure 3) was higher for phosphate (overall average of 4.66±1.41) than alkaline (3.81±1.21) treatments. In addition, time (day) and interaction between factors also were significantly different (P<.05) for lean color, fat color, % discoloration and overall acceptability. Results for color score generally followed the pattern as shown in Figure 3.

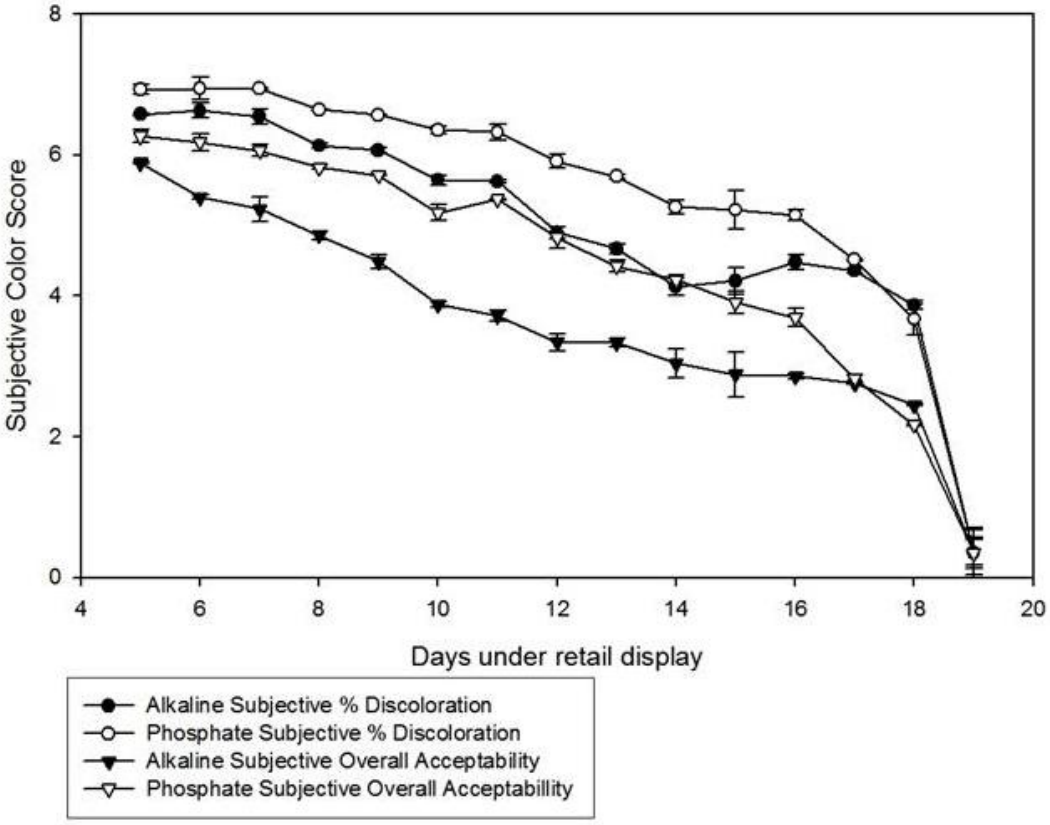

Figure 3. Subjective color evaluation on strip loin steaks after injection to 110% green weight with alkaline solution or phosphate based solution.

Objective Color Score (L*a*b). For L* value, a significant difference existed between treatments (P<.05) but not days (P=.98). Alkaline treated samples were lighter (44.83±3.0) than phosphate (40.18±2.2). Redness of the steaks decreased over time. Over 19 days of study, phosphate enhanced steaks were redder (20.97±4.39; P<.05) than alkaline enhanced steaks (15.62 ± 3.57). Analysis of b* or "yellowness" of steaks decreased over time for both treatments. However, there was no difference between treatments (P=.65).

Sensory Panel. Panelists found phosphate enhanced steaks more tender, juicier, and having less connective tissue (P<.05) than steaks enhanced with alkaline. The overall average for tenderness was 6.58±.61 for phosphate and 4.98±.82 for alkaline. In addition, the averages for juiciness were 6.03±.72 for phosphate solution and 4.48±.78 for alkaline. For connective tissue, the overall mean for phosphate treatment was 3.48±.34 and 3.10±.37 for alkaline. Means corresponding to overall acceptability were 5.40±.49 for phosphate and 4.13±.81 for alkaline. In addition, none of the traits analyzed

for sensory panel were significantly different with regard to day or the day by treatment interaction except for overall acceptability, which had a treatment by day interaction effect ($P<.05$) only.

Conclusion

Enhancement of select strip loin steaks with an alkaline solution at pH 10 was not as effective as the industry based phosphate injection solution. In general, it appears the pH 10 solution did not sufficiently raise final meat pH. This affected final meat color stability, water holding ability, and tenderness. However, an alkaline solution did significantly affect both aerobic and anaerobic microbial populations. Future research should be conducted to determine if higher levels of alkaline can sufficiently change meat pH so as to enhance color stability, water holding ability and tenderness while controlling microbial growth.

Acknowledgments

This project was financially supported by the National Cattlemen's Beef Assn. The authors thank John Dollarhide, Jennifer Green, Teresa Brown, Sujitha Pilla, Akhila Vasan, Miriam Velasco, Tyler Tate, Lin koh, Dennis Price, Kris Novotny, and Linda Guenther for their valuable help in completing this project.

Literature Cited

AMSA. 1991. Guidelines for meat color evaluation. American Meat Science Association.

AMSA. 1995. Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. American Meat Science Association.

AOAC International. 2003. Official methods of analysis of AOAC International. Association of Official Analytical Chemists (AOAC) International.

Block, G.A. et al. 1998. Am J Kidney Dis 31:607.

Buege, JA and Aust SD. 1978. Methods in Enzymology 52(Part C):302-10.

Foote, M.R. et al. 2004. J Anim Sci 82(1): 242-9.

Goodman, W.G. et al. 2004. Am J Kidney Dis 43:572-9

Ibels, L.S. et al. 1978. New England Journal of Medicine 298(3):122-6.

Morgan, J.B. et al.1991. J Anim Sci 69(8): 3274-83.

Perez-Rocha, L. and Varsi, A.L. 2003. The Natural Beef Market in the United States, Ag Marketing Resource Center, Kansas State University.

Robbins, K. et al. 2003. Meat Sci 65(2):721–9.

Tonelli M. et al. 2005. Circulation 112:2627-33.

Van, D. and Mireles DeWitt, Ch. 2007. Journal of Food Science Vol. 72 (1): C72-7.

Authors

Claudia A. Cerruto-Noya – Graduate Student

Deborah VanOverbeke – Assistant Professor

Christina A. Mireles DeWitt – Associate Professor