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Effect of the Programmed Nutrition Beef Program on moisture retention of cooked ground beef patties and enhanced strip loins[1,2]

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ABSTRACT:

This study evaluated the influence of the Programmed Nutrition Beef Program and exogenous growth promotants (**ExGP**) on water holding capacity characteristics of enhanced beef strip loins. Sixty, frozen strip loins, arranged in a 2 × 2 factorial treatment arrangement with dietary program serving as the first factor and use of ExGP as the second factor, were thawed, injected with an enhancement solution, and stored for 7 d. Loins from ExGP cattle possessed the ability to bind more ($P < 0.05$) water before pumping and bind less ($P < 0.05$) water after pumping and storage. Loin pH across treatments was similar ($P > 0.10$) before injection, but increased post-injection and after storage ($P < 0.01$). Treatments did not affect loin purge loss, steak cook loss, and expressible moisture ($P > 0.10$). The Programmed Nutrition Beef Program and use of ExGPs minimally impacted water holding capacity of enhanced frozen/thawed beef strip loins.

Keywords: Water-holding; Beef; Ractopamine; Feeding, Enhancement

1. Introduction

The goal of the beef industry is to produce a consistent, high quality product as efficiently as possible. Many different feedlot management strategies are employed to maximize efficiency including the utilization of different feed additives such as monensin (Rumensin; Elanco Animal Health, Greenfield IN) and tylosin (Tylan; Elanco Animal Health), and growth promoting technologies such as beta-adrenergic agonists and steroidal implants. Utilization of feed additives, implants, and beta-adrenergic agonists can greatly improve efficiency of beef production, but also can have negative consequences for beef quality (Winterholler et al., 2008). Beef palatability encompasses characteristics such as juiciness, tenderness, and flavor (Platter, Tatum, Belk, Scanga, & Smith, 2003), but water-holding capacity also impacts beef palatability. The ability of whole muscle or ground beef to retain moisture during storage and through processing is an important quality characteristic. It is established moisture loss from whole muscle products can impact the amount of salable product (Offer et al., 1989; Huff-Lonergan and Lonergan, 2005). Although cook yields of ground beef can be mostly dependent on fat content of the blend (Roth, McKeith, & Brewer, 1999), the ability of product to retain water during processing and cooking could also be important.

The Programmed Nutrition Beef Program (Alltech Inc., Nicholasville, KY) consists of two products that are designed to replace components of conventional feedlot diets. The Programmed Nutrition Beef Receiver is intended to be fed during the step-up period at the rate of 14 g•animal^{-1}•d^{-1}, while Programmed Nutrition Beef Finisher is fed for the remainder of the finishing period at a rate of 20 g•animal^{-1}•d^{-1}. Previous research by Phelps et al. (2014) reported the use of Programmed Nutrition Beef Program supplements in finishing feedlot diets decreased purge loss of strip loins aged 14 d compared to strip loins from steers fed a diet containing

conventional feedlot dietary components. Additionally, steaks from steers fed the Programmed Nutrition Beef Program supplements and steaks from steers that were not administered exogenous growth promotants (**ExGP**) had a decreased cook loss when compared to steaks from the conventional feedlot diet and administered ExGP, respectively. The objectives of this study were to evaluate influence of the Programmed Nutrition Beef Program and ExGPs on moisture retention of 85% lean ground beef patties, brine uptake and retention, objective water holding capacity, and Warner-Bratzler shear force (**WBSF**) of strip loins that were thawed from a frozen state and enhanced 110% with a salt/tripolyphosphate solution.

2. Materials and Methods

2.1 Animals

Crossbred feedlot steers (initial BW 383 kg ± 30; n = 64 pens; 16 pens/treatment; 8 steers/pen) were blocked by body weight and subjected to a randomized complete block design with 2 × 2 factorial treatment arrangement. Steers were separated into a conventional finishing program treatment (**CON**) or Alltech Programmed Nutrition Beef Program treatment (**PN**; Table 1). Conventional diets contained monensin, tylosin, vitamins A and E, and supplemented trace minerals including copper sulfate, cobalt carbonate, ethlenediamine dihydriodide, manganous sulfate sodium selenite, and zinc sulfate. The Programmed Nutrition Beef Receiver portion of the diet was included in the total mixed ration for the first 21 d at a rate of 14 g•animal^{-1}•d^{-1}. The Programmed Nutrition Beef Finisher was included in the total mixed ration at a rate of 20 g•animal^{-1}•d^{-1}for the final 154 d of the feeding period. The components of the Alltech Programmed Nutrition Beef Program diet were premixed into a ground corn carrier and subsequently blended into the total mixed ration. Both the Programmed Nutrition Beef Receiver and Finisher supplements contained a proprietary blend of organic trace elements, ascorbic acid,

Lactobacillus acidophilus fermentation product, *Enterococcus faecium* fermentation product, and selenium yeast. Additionally, Programmed Nutrition Beef Receiver included *Aspergillus niger* fermentation extract and Programmed Nutrition Beef Finisher included *Aspergillus oryzae* fermentation extract. Each diet was fed in conjunction with (**EGP+**) or in the absence of (**EGP–**) exogenous growth promotants (**ExGP**). Steers receiving **ExGP** were administered a Component E-S implant on d 1 of the study, reimplanted with Component TE-IS (Elanco Animal Health) on d 94, and fed ractopamine hydrochloride (**RAC**; Elanco Animal Health) at a rate of 400•d^{-1}•$steer^{-1}$ the final 28 d before harvest.

2.2 Loin collection

On d 175 of the study, animals were shipped 430 km to a commercial abattoir (Tyson Fresh Meats, Holcomb, KS) for harvest. After a 36-h chill, strip loins (Institutional Meat Purchase Specifications 180) were removed from the left side of 2 carcasses selected at random from each pen and were transported back to the Kansas State University Meats Laboratory. Loins were wet-aged for 14 d, 5 steaks were fabricated from the anterior portion of the *Longissimus lumborum* for another study (Phelps et al., 2014), and the remainder of the *Longissimus lumborum* was frozen at -40 ºC.

2.3 Loin Selection and Sampling

The posterior portion of the *Longissimus lumborum* of sixty frozen beef strip loins (n = 15 per treatment) were selected at random from the previous study (Phelps et al., 2014). For the injection study, loins selected were large enough to be injected (smallest loin = 0.58 kg), and also yielded 500 g of tissue for grinding. This resulted in a sample distribution that represented all 16 of the original weight blocks and 52 of the pens of the Phelps et al. (2014) study.

2.4 Loin processing and injection

Forty-eight hours prior to processing, strip loins were removed from the freezer and thawed at 2 ± 1 °C. Once thawed, all subcutaneous fat was removed from each loin, identified by loin number, and reserved for subsequent preparation of ground beef patties. From each trimmed loin, approximately 500 g of muscle was removed for grinding from the most anterior portion of each loin. Additionally, a 120-g sample was removed for measurement of expressible moisture (**EM**) and water binding ability (**WBA**) as described below. Before injection, pH was measured using a pH probe designed for use in meat (Model HI 99163; Hanna Instruments, Smithfield, RI) and loin sections were weighed. Loin sections were injected using a multi-needle injector (Model N50: Schröder Maschinenbau GmbH, Werther, Germany) with a brine solution (pH 7.95) which contained 5% sodium chloride and 3% sodium tripolyphosphate (Brifisol 85 Instant; BK Giulini Corp., Simi Valley, CA) to achieve a 0.5% sodium chloride and 0.3% sodium tripolyphosphate level within the muscle when pumped 10% over green weight. Following a 2-min rest period, loins were reweighed to ensure brine was assimilated to achieve 110% above green weight (average 111.14 ± 1.46%) and pH was recorded again before injected loins were vacuum packaged in 3-mm high-barrier vacuum pouches (Prime Source, Bunzyl Processor Division, Kansas City, MO). After storage for 7 d at 2 ± 1 ºC, loins were removed from packages, patted dry, and re-weighed for purge loss calculations [(injected weight-stored weight)/injected weight] × 100. At this time, pH was measured, a 120-g sample was removed for expressible moisture and WBA analyses, and a 2.54-cm thick steak was fabricated for determination of WBSF.

2.5 Grinding

To formulate a ground beef blend that was 85% lean and 15% fat, analyzed fat percentages from proximate analysis were used to calculate a blend for each sample. Using a

table top grinder (Model KG-12-FS; Pro-Cut, Houston, TX), lean and fat for each sample were ground separately through a 9.5-mm plate, blended together by hand, and then reground through a 3.2-mm plate. Once ground, two 1.2-cm thick × 10.7-cm wide patties weighing 112 g were formed from each sample.

2.6 Cooking and Warner-Bratzler shear force

All cooking and WBSF procedures were conducted according to the Meat Cookery and Sensory Guidelines (AMSA, 1995). Ground beef patties were weighed before cooking and cooked on a flat top grill (Model 106733; Walmart, Bentonville, AR) set to 132 ºC. Patties were turned at 1 min, turned again at 2 min, and then turned every 2 min until they reached an internal temperature of 71 ºC. A hypodermic needle thermometer consisting of a copper-constantan probe connected to a Doric Trendicator 410A monitor (VAS Engineering; San Francisco, CA) was used to monitor internal temperature. Patties were cooled at room temperature and once they could be handled they were reweighed to determine cook loss [(precooked weight-cooked weight)/precooked weight] ×100.

Prior to cooking, steaks were weighed and a thermocouple wire (30-gauge copper-constantan; Omega Engineering, Stamford, CT) was inserted into the geometric center of each steak to monitor internal temperature using a Doric Minitrend 205 monitor (VAS Engineering). Steaks were cooked on electric, open-hearth Hamilton Beach grills (Indoor/Outdoor; Southern Pines, NC) preheated to 204 °C. Steaks were turned when they reached an internal temperature of 40 ˚C, removed from grills at 70 ˚C, and allowed to cool until they could be handled before being reweighed to determine cook loss [(precooked weight-cooked weight)/precooked weight] ×100. Steaks were chilled for 24 h at 7 ± 1 ˚C, and six 1.27-cm cores were then removed from

each steak parallel to the muscle fiber. Cores were sheared once through the center using an INSTRON Model 5569 testing machine (Instron, Canton, MA) with a Warner-Bratzler shear head attached (100-kg compression load cell, crosshead speed of 250 mm/min).

2.7 Water binding ability and expressible moisture

The WBA of samples was measured by protein swelling analysis as described by Pietrasik and Janz (2009) with a modification. The modification made was the 100-g sample of muscle was cut into 0.5 × 0.5 × 0.5 cm pieces and then blended in a Waring blender (Waring Products Division, Hartford, CT) with 300 mL of distilled water. The remainder of the procedure was carried out as described by the authors.

Expressible moisture of samples was measured using the centrifugation method described by Jauregui, Regenstein, and Baker (1981). A 5-g sample of muscle was weighed, placed in a 50 mL conical tube on top of 25 g of 4-mm glass beads, and centrifuged at 900 × *g* for 10 min. After centrifugation, samples were removed from tubes and reweighed. Percent EM was calculated as [(initial weight-centrifuged weight)/initial weight] × 100.

2.8 Statistical analyses

Purge loss, cook loss, and WBSF data were analyzed as a randomized complete block design with a 2 × 2 factorial arrangement. Dietary program and ExGP served as the main effects and the animal weight block from Phelps et al. (2014) was the random effect. For loin pH, expressible moisture, and WBA, data were analyzed as repeated measures using a randomized complete block design with a 2 × 2 factorial treatment arrangement. Period served as the repeated measure with loin (observational unit) as the subject and compound symmetry as covariance structure. The PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) was

utilized and pair-wise comparisons between the least-squares means of the factor levels were computed using the PDIFF option of the LSMEANS statement. Differences were considered significant at $\alpha \leq 0.05$ and tendencies at $\alpha \leq 0.10$.

3. Results

3.1 Loin pH

Loin pH was recorded at three periods: before injection, after injection, and after 7-d of storage post injection (Table 2). There was no three-way interaction ($P = 0.55$) of dietary program × ExGP × period for pH. Also, the two-way interaction of dietary program × ExGP did not affect ($P = 0.39$) loin pH, but there was a tendency ($P = 0.10$) for a dietary program × period interaction to affect loin pH. Pre-injection, the pH of CON and PN loins was similar ($P = 0.75$), but post-injection PN loins had a greater ($P = 0.002$) pH than CON loins. Additionally, the post-injection pH of loins from both CON and PN loins increased ($P < 0.01$) by 0.37 and 0.32 units compared to their pre-injection pH, respectively. The pH recorded for both dietary treatments after 7 d of storage was similar to that recorded post-injection ($P > 0.15$); however, there was no difference ($P = 0.50$) in pH between the two dietary treatments after 7 d of storage. Also, pH data indicate an ExGP × period interaction ($P = 0.02$). Pre-injection pH was similar ($P = 0.88$) between EGP+ and EGP- loins. Post-injection pH of EGP- loins was greater ($P = 0.001$) than EGP+ loins, but pH recorded after 7-d of storage was similar ($P = 0.89$) between the two treatments. The pH of loins from the two dietary treatments differed with PN loins having a pH that was 0.04 units greater ($P = 0.02$) than CON loins. Additionally, there was a tendency ($P = 0.052$) for pH difference between the two ExGP treatments. Finally, as expected, period elicited an effect ($P < 0.01$) on the pH of loins. Before injection, the pH of loins was 5.53, and post-

injection pH was 0.32 units greater ($P < 0.01$). The pH recorded after 7 d of storage was comparable ($P = 0.77$) to post-injection pH.

3.2 Purge loss, cook loss, and WBSF

For purge loss, steak cook loss, and ground beef cook loss there was no two-way interaction of dietary program × ExGP (Table 3; $P > 0.34$). Also, the main effect of dietary program did not affect purge loss, steak cook loss, and ground beef cook loss ($P > 0.35$). Additionally, the ExGP effect did not impact purge loss or steak cook loss ($P > 0.23$), but there was a tendency ($P = 0.08$) for ExGP use to affect ground beef cook loss with ground beef patties from the EGP- tending to have a cook loss 1.06% greater than the EGP+ treatment.

Warner-Bratzler shear force was measured on strip loin steaks fabricated from enhanced loins (Table 3). There was a tendency ($P = 0.06$) for a dietary program × ExGP interaction to affect shear force. Dietary program influenced ($P = 0.05$) WBSF of steaks from enhanced loins. The shear force of steaks from PN loins was 0.15 kg less ($P = 0.05$) than the shear force of steaks from CON loins. The use of ExGP during the finishing phase did not impact ($P = 0.54$) shear force of steaks fabricated from enhanced loins.

3.3 Expressible moisture and water binding ability

There was no dietary program × ExGP × period interaction for EM or WBA (Table 4; $P > 0.36$). The two-way interactions of dietary program × ExGP or dietary program × period did not affect EM or WBA (Table 5; $P > 0.84$). The ExGP × period interaction did not impact ($P = 0.13$) EM, but did influence WBA ($P < 0.01$). Before injection, EGP+ loins had greater ($P = 0.01$) WBA compared to EGP- loins. After loins were injected and stored EGP- loins had a

206 greater ($P < 0.01$) WBA than EGP+ loins. Finally, the main effects of dietary program and ExGP
207 did not impact EM or WBA ($P > 0.21$).

208 **4. Discussion**

209 Beef palatability is influenced by many attributes, including tenderness, marbling,
210 texture, juiciness, and flavor profile (Miller, Carr, Ramsey, Crockett, & Hoover, 2001). These
211 attributes can be influenced by a wide range of factors, including genetics, age, diet, pre-harvest
212 management, and post-mortem processing (Hocquette, et al., 2012). Although the amount of
213 marbling often influences juiciness the most (O'Quinn et al., 2011), water holding capacity of
214 beef may also play a role in a consumer's beef eating experience (Winger & Hagyard, 1994).
215 Intrafiber water content has been suggested to impact meat tenderness (Currie &Wolfe, 1980)
216 and could potentially impact overall palatability of beef. In addition to influencing palatability,
217 poor water holding capacity of products can result in loss of salable weight for processors and
218 retailers (Huff-Lonergan and Lonergan, 2005).

219 Water holding capacity of beef and other meat products is largely influenced by pH
220 (Honikel, 2004). When meat reaches its isoelectric point the net charge of proteins is zero. This
221 effectively decreases the amount of water held between proteins as a result of the close
222 association between positively and negatively charged protein moieties. When the pH of meat is
223 transitioned away from its isoelectric point, water holding capacity improves (Aberle et al.,
224 2003). The increase in meat pH following the use of phosphates in brine solutions is well
225 documented (Smith, Simmon, McKeith, Bechtel, & Brady, 1984; Robbins et al., 2002; Wicklund
226 et al., 2005). In the present study, the common increase in pH due to brine injection was
227 duplicated. Loin pH recorded post-injection and after 7 d of storage were increased by 0.32 and

0.33 pH values, respectively when compared to pH recorded prior to injection. Similar to the present study, Wicklund et al. (2005) reported increases in muscle pH (0.32 units) when beef strip steaks were enhanced with a brine containing phosphates. Pietrasisk and Janz (2009) reported a smaller pH increase of 0.23 units in enhanced beef *Semitendinosus* steaks compared to non-enhanced steaks, while Robbins et al. (2002) observed that pH values of enhanced beef rounds were 0.28 units greater compared to non-enhanced rounds. Finally, Grobbel, Dikeman, Hunt, & Milliken (2008) reported that pH of enhanced *Longissimus*, *Semitendinosus*, and *Triceps brachii* steaks were 0.3, 0.2, and 0.2 units higher, respectively, compared to non-enhanced steaks. The current data also indicate that the ExGP × period interaction, dietary treatment, and ExGP treatment affected pH. When examining the differences closely, the differences in pH are all less than 0.10, which presumably would have a relatively small biological effect on water holding characteristics. Therefore, any treatment differences in water binding characteristics, cook loss, WBSF post-injection and storage occurred independent of pH.

Water binding ability measures the capacity of muscle to assimilate and retain additional water. In the current study, the WBA of EGP+ loins was greater than EGP- loins prior to enhancement and storage. After enhancement, WBA of EGP+ loins were less than EGP- loins. Because there were no differences in purge loss, the WBA data may indicate EGP+ were incapable of retaining additional moisture after they were enhanced 110%. Pietrasik and Janz (2009) found that freezing greatly reduced the WBA of meat and injection with a 1.5% phosphate solution increased WBA over injection with a 0.5% phosphate solution. Since all meat was frozen and the same brine solution was utilized on all loins, these factors can be eliminated as contributing to the ExGP difference. It is feasible that increased WBA of EGP+ loins was due to an increase in cross-sectional areas of type IIA and type IIX fibers as reported by Phelps et al.

(2014). Offer and Trinick (1983) stated that the majority of water present in meat is located within myofibrils, and these authors demonstrated that the degree of swelling by myofibrils observed after injecting brine solution was similar to the amount of water retained by the muscle. Therefore, since EGP+ loins possessed greater muscle fiber cross-sectional area as reported by Phelps et al. (2014), they likely possessed more myofibrils with which to bind the brine solution.

Previously, Phelps et al. (2014) reported that fresh loins from PN Beef Program supplemented steers had less purge loss during storage and also lost less weight during cooking compared to their CON counterparts. Additionally, the authors observed similar moisture retention properties for loins from cattle produced without ExGPs compared to those from cattle produced with ExGPs. The moisture retention advantages observed by Phelps et al. (2014) were expected to be duplicated in the meat systems examined in the present study. Data in this study indicate that when loins from all pre-harvest treatments were subjected to needle-injection enhancement, there are no differences in purge loss or cook loss. Numerous studies indicate that enhancement of fresh meat can affect both purge loss and weight loss during cooking. In a study in which purge loss was compared between non-enhanced and enhanced beef and bison steaks, Pietrasik, Dhanda, Shand, and Pegg (2006) reported that enhanced steaks lost 0.97% more purge than non-enhanced steaks. In contrast, Pietrasik and Janz (2009) reported that enhanced *Semitendinosus* steaks lost less purge than non-enhanced samples. McGee, Henry, Brooks, Ray, & Morgan (2003) reported that injecting beef round roasts with a brine decreased weight loss during cooking by 7.65% compared to non-injected controls, while Pietrasik and Shand (2005) reported injection of *Semimembranosus* roasts decreased weight loss during cooking by 11.9%.

When compared to the Phelps et al. (2014) results, the lack of purge and cook loss differences of enhanced loins and steaks in the current study may be a function of freezing and

thawing of the loins prior to enhancement. Expressible moisture, which is greatly related to moisture retention during storage and cooking, was unaffected by treatment before or after enhancement. This could indicate that freezing/thawing may have masked the fresh meat treatment related differences in moisture retention properties that were observed by Phelps et al. (2014). Boles and Swan (2002) reported that beef inside rounds that were frozen prior to injection retained 1% more brine solution than fresh injected rounds. The authors concluded that the disruption of the protein structure due to freezing (Polymendis, 1978) allowed for increased brine uptake. Pietrasik and Janz (2009) found that when frozen/thawed meat was stored 7 d post-injection, expressible moisture was drastically improved when compared to frozen/thawed meat stored 1 d post injection. Since Phelps et al. (2014) did not measure expressible moisture prior to freezing, it is impossible to determine the effect of freezing/thawing on this water holding characteristic.

Enhancement of beef cuts with brine solutions has become a more common production practice to alleviate tenderness issues (McGee et al., 2003). Regardless of treatment, average reduction in shear force compared to Phelps et al. (2014) reported values were 13.0 N for all steaks. Although it must be acknowledged the reduction in shear force of the enhanced steaks may also be a function of freezing. Robbins et al. (2002) reported shear force of enhanced *Semimembranosus* steaks was 0.52 kg lower than non-enhanced controls. In a study on the enhancement of beef chuck muscles, Molina, Johnson, West, & Gwartney (2005) found needle injection reduced WBSF of oven-roasted *Complexus* and *Subscapularis* steaks and grilled *Triceps brachii* steaks compared to non-injected controls by 11.7, 12.7, and 9.9 N, respectively. Also, Grobbel et al. (2008) examined the enhancement of *Longissimus lumborum*, *Semitendinosus*, and *Triceps brachii* steaks and reported needle injection decreased WBSF by

297 1.73, 1.25, and 1.25 kg, respectively compared to non-injected controls. In contrast to the results
298 of Phelps et al. (2014), the data in the present study indicated that enhanced CON steaks were 1.5
299 N more tender than enhanced PN steaks. Miller et al. (2001) reported that consumers can
300 distinguish between tenderness classifications at WBSF values of 0.30 kg, suggesting that
301 differences in tenderness between the enhanced CON and PN within the present study are
302 unlikely to be detectable by consumers.

303 The greatest improvement in shear force from the Phelps et al. (2014) values due to
304 enhancement was seen in EGP+ steaks, but there were no shear force differences for pre-harvest
305 use of ExGP versus not using ExGP when loins were enhanced. Enhancement reduced the shear
306 force of EGP+ by 15.2 N compared to values reported by Phelps et al. (2014). Brooks et al.
307 (2010) reported enhancement of strip loins from cattle fed zilpaterol hydrochloride reduced shear
308 force by 0.27 kg. The greater reduction in shear force in the present study compared to Brooks et
309 al. (2010) may have been influenced by freezing and thawing of loins prior to enhancement. As
310 stated before, ice crystals formed during freezing can disrupt protein structure. Two studies
311 (Hiner, Madsen, & Hankins, 1945; Shanks, Wulf, & Maddock, 2002) report lower WBSF of
312 steaks frozen prior to cooking compared to steaks cooked fresh. The combined effects of
313 moisture enhancement and freezing may have caused a much greater reduction in shear force.

314 Since Phelps et al. (2014) detected differences in fresh steak cook loss due to dietary
315 program or ExGP use, effect of treatments on cook loss from ground beef patties was examined.
316 In contrast to the fresh steak data, there were no differences in moisture loss during cooking of
317 ground beef patties. Two mechanisms could be responsible for this finding. First, as indicated
318 throughout this paper, the cellular disruption events associated with freezing/thawing the meat
319 may have negated the increased moisture retention associated with EGP- and PN treatments

reported by Phelps et al. (2014). This can be inferred by the fact that all treatment groups had similar expressible moisture percentages prior to pumping, therefore indicating they have similar water binding capacity. The second mechanism responsible for lack of moisture retention differences could be that fat was added to each sample to achieve the same final fat blend. Roth et al. (1999) found that reduced-fat patties possessed more water and less fat in the raw and cooked state than high-fat patties. More importantly, the authors reported that cook loss percentage mirrored fat content of the blend rather than water content of the blend. This would indicate that water binding is more important for ground beef blends made with a lower fat content, and the differences reported by Phelps et al. (2014) may have been masked by adding additional fat to the lean.

5. Conclusion

Injection of frozen/thawed beef loins with 0.5% sodium chloride and 0.3% sodium tripolyphosphate increased loin pH by up to 0.32 units after 7-d of storage. As expected, enhanced steaks had improved WBSF when compared to values reported by Phelps et al. (2014) fresh steaks, but no large differences in WBSF were detected between dietary programs and use of ExGP once steaks were enhanced. Expressible moisture analysis revealed that both before and after injection, there was no differences in treatments to hold water. This finding is reflected in the lack of pre-harvest treatment differences for purge loss and cook loss from ground beef and enhanced steaks during cooking. Although not measured, freezing of the meat may have influenced results in this study, thus warranting further investigation of the impact of freezing on water holding capacity of beef from cattle supplemented PN Beef Program supplements.

Tables

Table 1. Diets (dry basis) for steers fed conventional feedlot diets[†] or Alltech Programmed Nutrition Beef Program[‡]

Ingredient, %	Conventional	Alltech
Wet corn gluten feed	35.00	35.00
Steam-flaked corn	53.55	53.56
Ground wheat straw	7.00	7.00
Feed additive premix	2.16	-
Mineral/vitamin supplement	2.29	2.23
Programmed Nutrition supplement	-	2.21

[†]Conventional diets included vitamin A at 2,200 IU/kg; vitamin E at 22 IU/kg; copper sulfate to provide 10 mg/kg Cu; cobalt carbonate to provide 0.15 mg/kg Co; ethylenediamine dihydriodide to provide 0.5 mg/kg I; manganous sulfate to provide 60 mg/kg Mn; sodium selenite to provide 0.3 mg/kg Se; zinc sulfate to provide 60 mg/kg Zn on a dry matter basis; as well as 300 mg•animal^{-1}•d^{-1}of monensin and 90 mg•animal^{-1}•d^{-1}of tylosin (Elanco Animal Health; Greenfield, IN).

[‡]The Alltech diet included Programmed Nutrition Receiver in the total mixed ration for the first 21 days at the rate of 14 g·d^{-1}·steer^{-1} which contained: zinc proteinate to provide 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis as well as ascorbic acid, *Aspergillus oryzae* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Thereafter, Programmed Nutrition Finisher was included in the total mixed ration at the rate of 20 g·d^{-1}·steer^{-1}: 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis as well as ascorbic acid, *Aspergillus niger* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Both supplements were premixed into a ground corn carrier and subsequently blended into the total mixed ration.

Table 2. pH of beef strip loins from steers of steers fed conventional diets[†] or Alltech Programmed Nutrition Beef Program [‡] with and without exogenous growth promotants[§] recorded pre-injection, post-injection, and after 7 d of storage.

	Conventional		Alltech PN			*P* – value						
	EGP-	EGP+	EGP-	EGP+	SEM	Program	ExGP	Period	Prog ×Period	ExGP × Period	Prog × ExGP	Prog × ExGP × Period
pH					0.03	0.02	0.052	<0.01	0.10	0.02	0.39	0.55
Pre-injection	5.53	5.52	5.53	5.53								
Post-injection[1]	5.85	5.76	5.93	5.85								
After storage[2]	5.86	5.83	5.85	5.88								

[†]Conventional diets included vitamin A at 2,200 IU/kg; vitamin E at 22 IU/kg; copper sulfate to provide 10 mg/kg Cu; cobalt carbonate to provide 0.15 mg/kg Co; ethylenediamine dihydriodide to provide 0.5 mg/kg I; manganous sulfate to provide 60 mg/kg Mn; sodium selenite to provide 0.3 mg/kg Se; zinc sulfate to provide 60 mg/kg Zn on a dry matter basis; as well as 300 mg•animal^{-1}•d^{-1}of monensin and 90 mg•animal^{-1}•d^{-1} daily of tylosin (Elanco Animal Health; Greenfield, IN).

[‡] The Alltech diet included Programmed Nutrition Receiver in the total mixed ration for the first 21 days at the rate of 14 g•animal^{-1}•d^{-1} which contained zinc proteinate to provide 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus oryzae* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Thereafter, Programmed Nutrition Finisher was included in the total mixed ration at the rate of 20 g•animal^{-1}•d^{-1} which contained zinc proteinate to provide 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus niger* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Both supplements were premixed into a ground corn carrier and subsequently blended into the total mixed ration.

[§] Exogenous growth promotants included Component ES implant administered on d 1 of the experiment, Component TE-IS at reimplant, and ractopamine hydrochloride (Optaflexx) fed at 400 mg/animal daily for the final 28 d before harvest (all products from Elanco Animal Health).

[1] Recorded following injection after a 2 min rest.

[2] Recorded after 7 d of storage.

Table 3. Purge loss of injected beef *Longissimus lumborum*, cook loss of injected beef *Longissimus* steaks and ground beef, and Warner-Bratzler shear force (WBSF) from steers fed conventional diets[†] or Alltech Programmed Nutrition Beef Program[‡] with and without exogenous growth promotants[§]

	Conventional		Alltech PN			*P* - value		
Item	EGP-	EGP+	EGP-	EGP+	SEM	Program	ExGP	Prog × ExGP
Purge loss[1], %	1.31	1.51	1.45	1.09	0.23	0.54	0.72	0.23
Steak cook loss[2], %	22.89	21.02	23.28	22.60	1.03	0.35	0.23	0.57
Ground beef cook loss[2], %	23.36	21.72	22.89	22.41	0.59	0.86	0.08	0.34
WBSF, N	20.9	19.0	18.0	19.0	1.0	0.05	0.54	0.06

[†]Conventional diets included vitamin A at 2,200 IU/kg; vitamin E at 22 IU/kg; copper sulfate to provide 10 mg/kg Cu; cobalt carbonate to provide 0.15 mg/kg Co; ethylenediamine dihydriodide to provide 0.5 mg/kg I; manganous sulfate to provide 60 mg/kg Mn; sodium selenite to provide 0.3 mg/kg Se; zinc sulfate to provide 60 mg/kg Zn on a dry matter basis; as well as 300 mg/animal daily of monensin and 90 mg/animal daily of tylosin (Elanco Animal Health; Greenfield, IN).

[‡] The Alltech diet included Programmed Nutrition Receiver in the total mixed ration for the first 21 days at the rate of 14 g/animal daily which contained zinc proteinate to provide 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus oryzae* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Thereafter, Programmed Nutrition Finisher was included in the total mixed ration at the rate of 20 g/animal daily which contained zinc proteinate to provide 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus niger*

fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Both supplements were premixed into a ground corn carrier and subsequently blended into the total mixed ration.

[§] Exogenous growth promotants included Component ES implant administered on d 1 of the experiment, Component TE-IS at reimplant, and ractopamine hydrochloride (Optaflexx) fed at 400 mg/animal daily for the final 28 d before harvest (all products from Elanco Animal Health).

[1] [(pumped weight-stored weight)/pumped weight] × 100.

[2] [(pre-cook weight-cooked weight)/pre-cook weight] × 100.

Table 4. Expressible moisture and water binding ability of beef strip loins from steers fed conventional diets[†] or Alltech Programmed Nutrition Beef Program[‡] with and without exogenous growth promotants[§] before injection and after 7 d of storage.

Item	Conventional		Alltech PN		SEM	*P* – value						
	EGP-	EGP+	EGP-	EGP+		Program	ExGP	Period	Prog × Period	ExGP × Period	Prog × ExGP	Prog × ExGP × Period
Expressible moisture[1], %					0.76	0.97	0.90	0.67	0.99	0.13	0.84	0.36
Before injection	11.12	10.03	10.84	10.36								
After storage	10.20	11.36	10.75	10.85								
Water binding ability[2],%					2.05	0.96	0.21	<0.01	0.70	<0.01	0.50	0.99
Before injection	19.86	31.64	20.42	28.88								
After storage	32.79	25.61	34.21	25.49								

[†]Conventional diets included vitamin A at 2,200 IU/kg; vitamin E at 22 IU/kg; copper sulfate to provide 10 mg/kg Cu; cobalt carbonate to provide 0.15 mg/kg Co; ethylenediamine dihydriodide to provide 0.5 mg/kg I; manganous sulfate to provide 60 mg/kg Mn; sodium selenite to provide 0.3 mg/kg Se; zinc sulfate to provide 60 mg/kg Zn on a dry matter basis; as well as 300 mg•animal^{-1}•d^{-1} of monensin and 90 mg•animal^{-1}•d^{-1} of tylosin (Elanco Animal Health; Greenfield, IN).

[‡] The Alltech diet included Programmed Nutrition Receiver in the total mixed ration for the first 21 days at the rate of 14 g•animal^{-1}•d^{-1} which contained zinc proteinate to provide 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus oryzae* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Thereafter, Programmed Nutrition Finisher was included in the total mixed ration at the rate of 20 g•animal^{-1}•d^{-1} which contained zinc proteinate to provide 10.7 mg/kg Zn; manganese proteinate to provide 7.1 mg/kg manganese; cobalt proteinate to provide 1.2 mg/kg cobalt; copper proteinate to provide 2.9 mg/kg copper; calcium iodate to provide 0.6 mg/kg iodine; selenium yeast to provide 0.31 mg/kg selenium on a dry matter basis; as well as ascorbic acid, *Aspergillus niger* fermentation product, *Lactobacillus acidophilus* fermentation product, and *Enterococcus faecium* fermentation product. Both supplements were premixed into a ground corn carrier and subsequently blended into the total mixed ration.

[§] Exogenous growth promotants included Component ES implant administered on d 1 of the experiment, Component TE-IS at reimplant, and ractopamine hydrochloride (Optaflexx) fed at 400 mg/animal daily for the final 28 d before harvest (all products from Elanco Animal Health).

[1] [(Initial weight-centrifuged weight)/initial weight] × 100.

[2] Calculated as 300-(11.43 × supernatant volume).

Literature Cited

Aberle, E. D., Forrest, J. C., Gerrard, D. E., & Mills, E. W. (2003). Principles of meat science (4th ed.). Dubuque, IA: Kendall/Hunt Publishing Co.

AMSA. (1995). Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurement of fresh meat. Centennial, CO: American Meat Science Association in cooperation with the National Livestock and Meat Board, now the National Cattleman's Beef Association.

Boles, J. A., & Swan, J. E. (2002). Meat and storage effects on processing characteristics of beef roasts. *Meat Science*, 62, 121-127.

Brooks, J. C., Mehaffey, J. M., Collins, J. A., Rogers, H. R., Legako, J., Johnson B. J., Lawerenc, T, Allen, D. M., Streeter, M. N., Nichols, W. T., Hutcheson, J. P., Yates, D. A., & Miller, M. F. (2010). Moisture enhancement and blade tenderization effects on the shear force and palatability of strip loin steaks from beef cattle fed zilpaterol hydrochloride. *Journal of Animal Science*, 88, 1809-1816.

Currie, R. W. & Wolfe, F. H. (1980). Rigor related changes in mechanical properties (tensile and adhesive) and extracellular space in beef muscle. *Meat Science*, 4, 123-143.

Grobbel, J. P, Dikeman, M. E., Hunt, M. C., & Milliken, G. A. (2008). Effects of different packaging methods and injection-enhancement on beef tenderness, sensory attributes, desmin degradation, and display color. *Journal of Animal Science*, 86, 2697-2710.

Hiner, R. L., Madsen, L. L., & Hankins, O. G. (1945). Histological characteristics, tenderness, and drip losses of beef in relation to temperature of freezing. *Journal of Food Science*, 10, 312-324.

Hocquette, J., Botreau, R., Picard, B., Alain, J., Pethick, D. W., & Scollan, N. D. (2012). Opportunities for predicting and manipulating beef quality. *Meat Science*, 92, 197-209.

Honikel, K. O. (2004). Water-holding capacity of meat. M. F. W. te Pas, M. E. Everts, & H. P. Haagsman (Eds.), *Muscle Development of Livestock Animals* (pp. 389-400). Cambridge, MA: CABI Publishing.

Huff-Lonergan, E. and Lonergan, S. M. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Meat Science*, 71, 194-204.

Jauregui, C. A., Regenstein, J. M., & Baker, R. C. (1981). A simple centrifugal method for measuring expressible moisture, a water-binding property of muscle foods. *Journal of Food Science*, 46, 1271.

McGee, M. R., Henry, K .L., Brooks, J. C., Ray, F. K., & Morgan, J. B. (2003). Injection of sodium chloride, sodium tripolyphosphate, and sodium lactate improves Warner-Bratzler shear and sensory characteristics of pre-cooked inside round roasts. *Meat Science*, 64, 273-277.

Miller, M. F., Carr, M. A., Ramsey, C. B., Crockett, K. L., & Hoover, L. C. (2001). Consumer thresholds for establishing the value of beef tenderness. *Journal of Animal Science*, 79, 3062-3068.

Molina, M. E., Johnson, D. D., West, R. L., & Gwartney, B. L. (2005). Enhancing palatability traits in beef chuck muscles. *Meat Science*, 71, 52-61.

Offer, G. & Trinick, J. (1983). On the mechanism of water holding in meat: the swelling and shrinking of myofibrils. *Meat Science*, 8, 245-281.

Offer, G., Knight, P., Jeacoke, R., Almond, R., Cousins, T., Elsey, J., Parsons, N., Sharp, A., Starr, R., & Purslow, P. (1989). The structural basis of the water-holding, appearance and toughness of meat and meat products. *Food Microstructure*, 8, 151-170.

O'Quinn, T. G., Brooks, J. C., Polkinghorne, R. J., Garmyn, A. J., Johnson, B. J., Starkey, J. D., Rathmann, R. J., & M. F. Miller. (2012). Consumer assessment of beef strip loin steaks of varying fat levels. *Journal of Animal Science*, 90, 626-634.

Phelps, K. J., Drouillard, J. S., Jennings, J. S., Depenbusch, B. E., Van Bibber-Krueger, C. L., Miller, K. A., Vaughn, M. A., Burnett, D. D., Ebarb, S. M., Houser, T. A., Johnson, S. E., & Gonzalez, J. M. (2014). Effects of the PN Beef Program on meat quality characteristics. *Journal of Animal Science*, 92, 1780-1791.

Pietrasik, J., & Janz, J. A. M. (2009). Influence of freezing and thawing on the hydration characteristics, quality, and consumer acceptance of whole muscle beef injected with solutions of salt and phosphate. *Meat Science*, 81, 523-532.

Pietrasik, Z., Dhanda, J. S., Shand, P. J., & Pegg, R. B. (2006). Influence of injection, packaging, and storage conditions on the quality of beef and bison steaks. *Journal of Food Science*, 71, 110-118.

Pietrasik, Z., & Shand, P. J. (2005). Effects of mechanical tenderization and moisture enhancement on the processing characteristics and tenderness of beef *semimembranosus* roasts. *Meat Science*, 71, 498-505.

Platter, W. J., Tatum, J. D., Belk, K. E., Scanga, J. A., & Smith, G. C. (2003). Effects of repetitive use of hormonal implants on beef carcass quality, tenderness, and consumer ratings of beef palatability. *Journal of Animal Science*, 81, 984-996.

Polymenidis, A. (1978). Chilling and freezing meat. *Fleischwirtschaft*, 58, 728-732.

Robbins, K., Jensen, J., Ryan, K. J., Homco-Ryan, C., McKeith, F. K., & Brewer, M. S. (2002). Enhancement effects on sensory and retail display characteristics of beef round. *Journal of Muscle Foods*, 13, 279-288.

Roth, D. M., McKeith, F. K., & Brewer, M. S. (1999). Processing parameter effects on sensory and instrumental texture characteristics of reduced-fat ground beef patties. *Journal of Muscle Foods*, 10, 163-176.

Shanks, B. C., Wulf, D. M., & Maddock, R. J. (2002). Technical note: The effect of freezing on Warner-Bratzler shear force values of beef longissimus steaks across several postmortem aging periods. *Journal of Animal Science*, 80, 2122-2125.

Smith, L. A., Simmons, S. L., McKeith, F. K., Bechtel, P. J., & Brady, P. L. (1984). Effects of sodium tripolyphosphate on physical and sensory properties of beef and pork roasts. *Journal of Food Science*, 49, 1636-1637. 1641.

Wicklund, S. E., Homco-Ryan, C., Ryan, K. J., McKeith, F. K., McFarlane, B. J., & Brewer, M. S. (2005). Aging and enhancement effects on quality characteristics of beef strip steaks. *Journal of Food Science*, 70, 242-248.

Winger, R. J., & Hagyard, C. J. (1994). Juiciness- its importance and some contributing factors. In A. M. Pearson, & T. R. Dutson (Eds.), *Quality attributes and their measurement in*

meat, poultry, and fish products: Advances in meat research (pp. 94-124). New York: Perseus Books Group.

Winterholler, S. J., Parsons, G. L., Walker, D. K., Quinn, M. J., Drouillard, J. S., & Johnson, B. J. (2008). Effect of management system on response to ractopamine-HCl in yearling steers. *Journal of Animal Science*, 86, 2401-2414.