Needle-Free Injection Enhancement of Beef Strip Loins with Phosphate and Salt Has Potential to Improve Yield, Tenderness, and Juiciness but Harm Texture and Flavor[1]

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Introduction

Meat tenderness is the most important palatability attribute affecting consumers' overall eating experience. Injection enhancement and blade tenderization have long been used to improve this important trait. Injection enhancement has been shown to improve tenderness, juiciness, color stability, and cooking yield, but not all solutions have been adequately evaluated. Thus, there is a need to conduct research on the effectiveness of common enhancement solutions. We published results from an extensive study comparing a solution of phosphate, salt, and rosemary with a solution of calcium lactate and rosemary injected by using traditional needle injection. There were no differences in Warner-Bratzler shear force values between treatments, but trained panelists scored steaks enhanced with calcium lactate and rosemary to be less tender and juicy than steaks enhanced with phosphate, salt, and rosemary. However, steaks enhanced with the phosphate solution had a higher incidence of metallic and salty off-flavors, a darker initial color, and more color deterioration. Because needle-free injection enhancement is relatively similar to traditional needle-injection enhancement with regard to food safety, it should be evaluated for its effects on meat color, instrumental tenderness, sensory traits, and yields.

Objectives of this research were to determine the effects of injection method (needle-free vs. needle injection) and solution (calcium lactate vs. phosphate solution) on meat color, instrumental tenderness, sensory traits, pump yield, and cooking loss of beef *Longissimus lumborum* muscles.

Experimental Procedures

Experiment 1

Beef *Longissimus* muscles (n = 15) from USDA Select, A-maturity carcasses were obtained from a commercial abattoir at 2 days postmortem and stored at 4°F until 9 days postmortem. Fat was trimmed to 0.13 in., and each loin was halved and then assigned randomly to one of two injection treatments: needle or needle-free. A Plexiglas template with holes spaced 0.38 in. apart was used to space the injection sites for needle-free injection. In the needle-free treatment, the dorsal and ventral sides of the strip loins were injected at 25 psi. Needles on the needle injector were spaced 0.70 × 1.0 in. apart. The injector was set to achieve a desired pump yield of 12% by injecting from the fat side only. A solution containing 2.2% salt, 4.4% sodium tri-polyphosphate,

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and 1.5% potassium lactate was used for injection. After injection, each muscle section was allowed to drain for 30 minutes before a final weight was taken.

After injection, four steaks (1.0-in. thick) were cut from the anterior end of each muscle section. Two of these steaks were placed on separate Styrofoam trays, covered with polyvinyl chloride film, and placed into simulated retail display for visual color evaluation. The remaining two steaks were vacuum packaged; one was stored at 4°F for 4 days until it was used for *Longissimus* slice shear force measurement, and the other was frozen for sensory analysis. Steaks used for visual color evaluation were displayed under continuous fluorescent lighting for 5 days at 4°F. Trained visual color panelists (n = 8) evaluated initial color on day 0 of display and display color and surface discoloration on days 1 to 5 of display.

On day 13 postmortem, shear force steaks were cooked in a forced-air convection oven set at 325°F to an internal temperature of 158°F and allowed to cool for 2 minutes at room temperature before a 0.4-in.-thick, 2.0-in.-long slice was removed from the lateral end of each steak parallel to the muscle fibers and sheared perpendicular to the muscle with an Instron Universal Testing Machine. Eight trained panelists evaluated steaks. Steaks were thawed overnight, cooked to 158°F, sliced into 1.0 × 0.5 × 0.5 in. samples, and served warm to panelists. Panelists also recorded verbal descriptors for abnormal texture, such as "slick," "rubbery," or "mushy."

Experiment 2

For each of two replications on 2 separate days, 15 beef *Longissimus* muscles from strip loins from USDA Select, A-maturity carcasses were obtained at 2 days postmortem and stored at 4°F until 5 days postmortem. Fat was trimmed to 0.13 in., and each strip loin was halved. Then, the halves were assigned randomly to one of four treatments: needle injected with the same calcium lactate solution used in experiment 1, (2) needle-free injected with the same calcium lactate solution, (3) needle injected with the same phosphate solution used in experiment 1, or (4) needle-free injected with the same phosphate solution. Injection enhancement, slice shear force, and sensory panel evaluation conducted as in experiment 1.

Display color and discoloration data were analyzed as a split-plot design using the mixed model procedure (PROC MIXED) of SAS (SAS Institute, Inc., Cary, NC). Sensory, cooking loss, pump yield, and slice shear force data were analyzed using analysis of variance (ANOVA) in the PROC MIXED procedure in SAS.

Results and Discussion

Experiment 1

There was considerable variation in pump yield for both injection methods; however, there was a trend ($P=0.08$) toward higher pump yields for the needle-free treatment. Treatment had no effect ($P>0.05$) on initial color scores at day 0. However, needle-injected steaks were darker on day 1 of display but not after day 1. As expected, discoloration scores indicated that steaks from both treatments had increasing amounts of discoloration as day of display increased ($P<0.0001$); the greatest increase occurred after day 3.

Slice shear force values showed that all steaks were tender, but steaks from loins injected using the needle-free technology (17.0 lb) were more tender ($P<0.05$) than those from loins injected with the traditional needle injector (22.27 lb). The trend ($P=0.08$) toward higher pump yields for the needle-free treatment could have played a role in the greater tenderness of the needle-free steaks.

Loins injected with the needle-free device had lower cooking loss percentages ($P<0.05$) than loins injected with the needle injector, perhaps because there was a trend ($P=0.08$) toward higher pump yields with the needle-free treatment. It is logical that any increase in distribution of the enhancement solution throughout the meat that happened with needle-free injection could have reduced cooking losses.

Myofibrillar tenderness, juiciness, connective tissue amount, and overall tenderness were not different ($P>0.05$) between treatments. Steaks from the needle-free treatment had less ($P<0.05$) beef flavor intensity than steaks from the needle treatment (3.6 vs. 4.9; Figure 1). Panelists also reported greater ($P<0.05$) off-flavor scores in the needle-free treatment (3.9) than in the needle treatment (5.1). The most common off-flavors were salty, soapy, livery, and metallic. These off-flavor descriptors were reported fairly evenly for both treatments; the primary difference was that intensity of the off-flavors was greater for the needle-free treatment. The soapy descriptor was used almost exclusively for steaks in the needle-free treatment. The salty off-flavor was the most common descriptor, and almost every sample in both treatments received that descriptor. A few comments from panelists indicated that steaks in the needle-free treatment had a slick, mushy texture.

Experiment 2

The needle-free loins injected with the phosphate solution had higher ($P<0.05$) pump yields than loins in all other treatment combinations. There was no difference ($P>0.05$) between needle and needle-free treatments when the calcium lactate solution was used. Neither needle nor needle-free loins injected with the calcium lactate solution had pump yields that differed from those of the needle-injected loins injected with the phosphate solution.

Steaks injected with the phosphate solution had lower ($P<0.05$) slice shear force values than steaks injected with the calcium lactate solution, but there were no differences ($P>0.05$) in slice shear force between needle and needle-free treatments, which contradicts results from experiment 1. There was no difference ($P>0.05$) in cooking loss between needle and needle-free injection for loins injected with calcium lactate; however, loins injected with calcium lactate had a higher (Figure 2, $P<0.05$) cooking loss than loins injected with the phosphate solution.

Panelists did not detect differences ($P>0.05$) between needle and needle-free treatments for myofibrillar tenderness, juiciness, beef flavor intensity, connective tissue amount, and overall tenderness. However, the needle-injected steaks had fewer ($P<0.05$) off-flavors. Salty was the most common off-flavor, and it was far more common to loins injected with the phosphate solution, which contained 2.2% salt. Texture scores were higher ($P<0.05$) for needle-injected steaks, meaning that panelists perceived the texture of needle-injected steaks to be closer to that of normal, nonenhanced steaks. The most common descriptors for abnormal texture were mealy, gelatin, crunchy, slick, or mushy.

The gelatin descriptor was more common among steaks enhanced with the phosphate solution, whereas steaks enhanced with the calcium lactate solution more commonly received a mealy texture descriptor.

Myofibrillar tenderness, juiciness, connective tissue amount, and overall tenderness were scored lower (P<0.05) for loins enhanced with the calcium lactate solution than for loins enhanced with the phosphate solution (Figure 3). Steaks enhanced with calcium lactate had a lower (P<0.05) incidence of off-flavors and a more normal texture.

Implications

Literature comparing needle-free injection enhancement with traditional needle injection enhancement was, until now, not available. Enhancement with needle-free vs. needle injection did not have a detrimental effect on meat color and resulted in reduced cooking loss. However, needle-free injection resulted in more off-flavor intensity, with the soapy descriptor being exclusive to the needle-free treatment. Abnormal textures described as slick or mushy were also associated with needle-free steaks. Enhancement with the phosphate solution resulted in greater myofibrillar and overall tenderness, juiciness, and cooking yield with less connective tissue but also caused more abnormal texture, described as gelatin, and more off-flavor intensity, with common descriptors of salty or livery. Additional research needs to be conducted to develop a prototype needle-free injector with multiple injection tips to allow a more direct comparison of needle and needle-free injection with or without enhancement solutions.

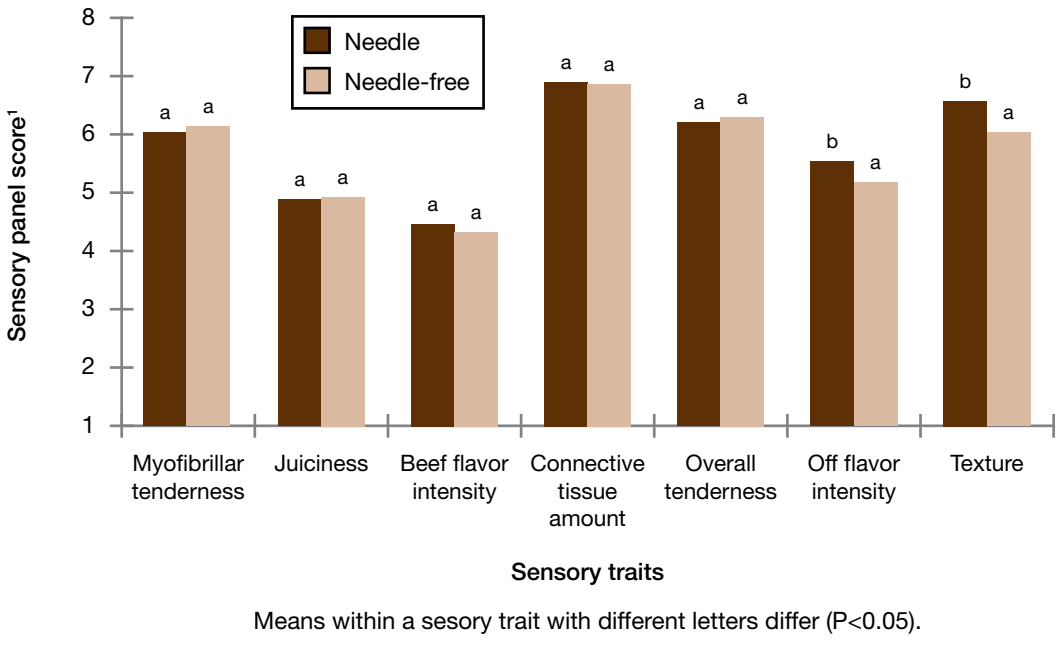

Figure 1. Trained sensory panel scores for *Longissimus lumborum* steaks injected with a needle or needle-free method (experiment 1).

[1] Myofibrillar and overall tenderness scale: 1 = extremely tough, 4 = slightly tough, 8 = extremely tender; Juiciness scale: 1 = extremely dry, 4 = slightly dry, 8 = extremely juicy; Beef flavor intensity scale: 1 = extremely bland, 4 = slightly bland, 8 = abundant; Connective tissue amount scale: 1 = abundant, 4 = moderate, 8 = none; Off-flavor intensity scale: 1 = abundant, 4 = moderate, 8 = none; Texture scale: 1 = extremely abnormal, 4 = slightly abnormal, 8 = extremely normal.

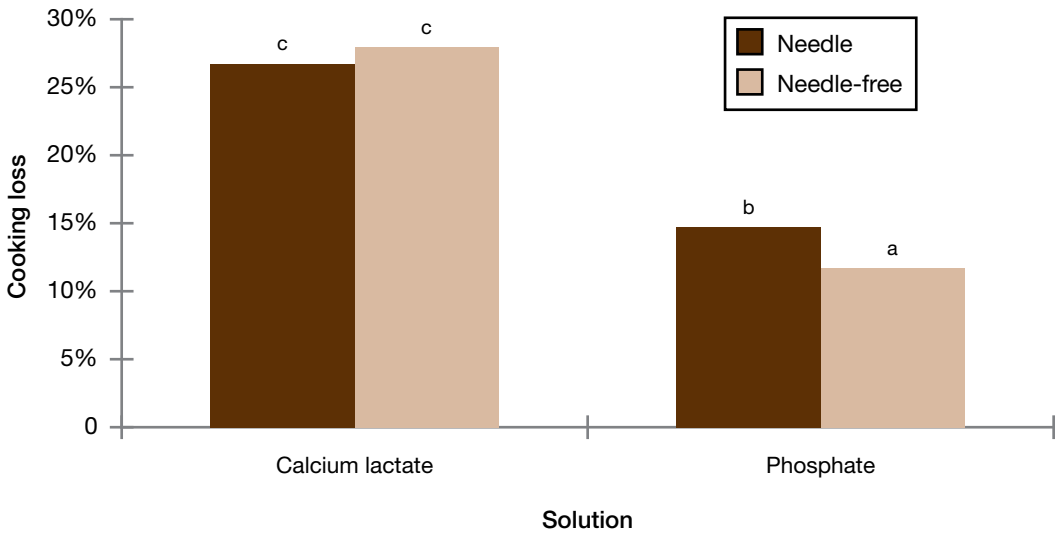

Figure 2. Cooking loss for *Longissimus lumborum* steaks injected with a calcium lactate or phosphate solution with a needle or needle-free method (experiment 1).

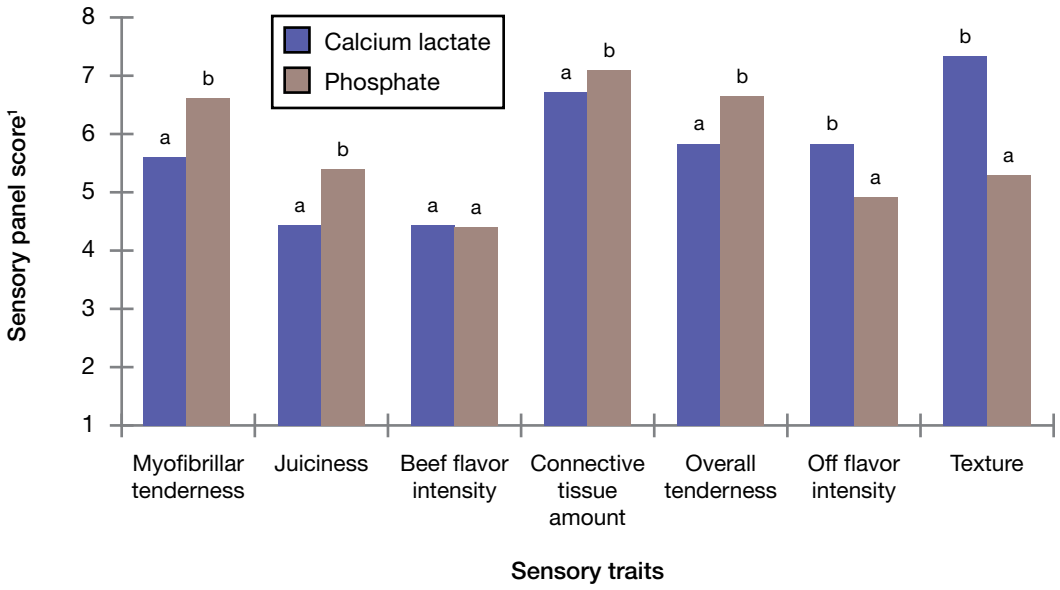

Figure 3. Trained sensory panel scores for *Longissimus lumborum* steaks injection enhanced with a calcium lactate or phosphate solution (experiment 2).
[1] Myofibrillar and overall tenderness scale: 1 = extremely tough, 4 = slightly tough, 8 = extremely tender; Juiciness scale: 1 = extremely dry, 4 = slightly dry, 8 = extremely juicy; Beef flavor intensity scale: 1 = extremely bland, 4 = slightly bland, 8 = abundant; Connective tissue amount scale: 1 = abundant, 4 = moderate, 8 = none; Off-flavor intensity scale: 1 = abundant, 4 = moderate, 8 = none; Texture scale: 1 = extremely abnormal, 4 = slightly abnormal, 8 = extremely normal.