Reprinted from Journal of Food Science.

L. C. HINNERGARDT, S. R. DRAKE and R. A. KLUTER
Food Engineering Lab., U.S. Army Natick Laboratories, Natick, MA 01760

GRILLED FREEZE-DRIED STEAKS. Effects of Mechanical Tenderization Plus Phosphate and Salt

INTRODUCTION

A TOUGH WOODY TEXTURE has long been associated with freeze-dried beef steaks and pork chops (Bird, 1965; Penny et al., 1963). Various attempts have been made to increase the tenderness of raw and precooked freeze-dried beef and pork slices. Tuomy et al. (1963) indicated that prolonged and/or higher internal cooking temperatures would result in a more tender freeze-dried beef steak. Hinnergardt and Burger (1975) investigated this theory and found that this was in fact, the case. However, the extra cooking necessary to produce an observable increase in tenderness also imparted an undesirable dry-mouth feel to the precooked freeze-dried steak. Hinnergardt and Burger (1975) did find greatly improved rehydration and rehydrated meat texture when roast beef was sliced 1.6 mm thick. Penny et al. (1963) reported an improvement in beef texture when the beef had been treated with a pre-slaughter injection of adrenaline. The adrenaline-treated samples had a high ultimate pH of 6.7 and were more juicy and less woody than the control samples with an ultimate pH of 5.6. They also observed that the dehydrated beef with a high ultimate pH showed less deterioration of texture, flavor and color during storage at 37°C. Improved hydration of meat was also found by Wismer-Pedersen (1965), to be associated with high pH values. Bouton et al. (1973) stated that beef tenderness increased linearly with increasing pH, particularly, when the ultimate pH is over 6.0. With pH values less than 6.0, they felt there were too many factors affecting tenderness to always find a fixed relationship between tenderness and pH values.

Since pre-slaughter treatment of beef to attain a high ultimate pH is frequently difficult or impossible, some workers have attempted to raise the ultimate pH of post-slaughter muscle to increase both tenderness and water-holding capacity. Shults et al. (1972) summarizes some of the work done using condensed phosphates on pH adjustment of fresh beef. This summary indicated a combination of salt and phosphate produced the most water retention. Their study not only confirmed this fact, but indicated Na tripolyphosphate and tetra sodium pyrophosphate had the most effect on water retention and pH adjustment. However, a combination of NaCl and 0.5% TPP resulted in the least amount of shrink during 180 min of heating at 60°C. They concluded that the synergistic effects of TPP with small amounts of NaCl (0.5–1.5%) presented the possibility of obtaining precooked beef items with a low shrink and no, or only a slight, salty taste. This could be an important observation for preparation of cooked beef for freeze-dehydration because more juice could be retained during cooking to prevent the dryness often observed with meat cooked for freeze dehydration. Wismer-Pedersen (1965) injected pork loins with ethylenediaminetetraacetate (EDTA) and pyrophosphate. He found the EDTA facilitated water penetration while the pyrophosphate improved the water-binding capacity of the meat. Warner-Bratzler shear values showed an improved texture of the treated samples.

Hamdy et al. (1959) tried to improve rehydration of freeze-dried meats by rehydrating them in solutions of 0.2M NaCl, 0.01M KCl and 0.05M sodium ascorbate. These treatments seemed to improve the texture and water-holding capacity (WHC) of the freeze-dried meats. Calcium and magnesium chlorides added to the reconstitution water increased the WHC but added an objectionable taste to the meat. The effect of the infused modifier solution added to the meat prior to freeze drying was also carried over to the rehydrated meat samples.

Table 1—Technological panel and penetrometer results of grilled, freeze-dried steaks treated with and w/o mechanical tenderization, and with and w/o a solution of PO_4 and NaCl

	No mechanical tenderization or PO_4 [a]	With PO_4/NaCl	With mechanical tenderization	With mechanical tenderization and PO_4/NaCl
Tenderness[c]	2.87d	4.22c	5.05b	5.95a
Penetrometer[b]	10.86 ± 2.06	9.02 ± 2.06	6.36 ± 1.20	5.15d ± 0.95
Cutability[d]	2.67c	4.55b	5.97a	6.55a
Residue[e]	5.57a	4.60ab	4.22b	3.87b
Juiciness[f]	3.20c	4.80a	3.97bc	4.40ab
Percent rehydration[g]	50.00c ± 5.36	56.61a ± 5.07	53.61b ± 3.68	55.96ab ± 3.46

[a] Means in a row not followed by a common letter differ significantly at the 1% level of probability as determined by the Neuman-Keuls test.
[b] Penetration was accomplished according to the method of Hinnergardt and Tuomy (1970). Shear force values = lb force required to penetrate a 1.27 cm thick beef steak.
[c] Tenderness is the overall effort required to chew a sample on the first and subsequent chews. (1 = extremely tough; 9 = extremely tender).
[d] Cutability is the degree of difficulty or ease one experiences in biting through a sample on one or more tries when the sample is initially put in the mouth. (1 = extremely difficult; 9 = extremely easy).
[e] Residue is the amount of material remaining in the mouth just before swallowing the sample. (1 = none; 9 = greatest amount).
[f] Juiciness is the degree to which one can feel free liquid in the mouth. (1 = extremely dry; 9 = extremely juicy).
[g] $\frac{\text{Rehydrated wt} - \text{dry wt}}{\text{rehydrated wt}} \times 100 = \%$ moisture.

Even though the treatments described resulted in improved texture of freeze-dried meat, apparently a great deal of variation was still observed in the rehydration and texture of treated freeze-dried meat. It appeared to the authors of this paper that use of a Bettcher needle tenderizer might reduce the variation in texture and rehydration of cooked freeze-dried meats without altering the rehydrated cooked meat appearance. The authors have been unable to find literature regarding the use of the Bettcher mechanical tenderizer. However, its use to mechanically tenderize wholesale cuts of beef is known.

The following study was undertaken to determine the effect of a phosphate and salt solution in combination with mechanical tenderization of meat prior to cooking and freeze-dehydration on the juiciness and tenderness of precooked freeze-dried beef.

MATERIALS & METHODS

Thirty-two USDA Choice top rounds, 7 to 10 days postmortem were obtained from a commercial source. The rounds were individually wrapped in freezer paper, and stored at –23°C for 1 wk. The rounds were then randomly divided into four lots, by random selection equilibrated to a temperature of 4.4°C, and the semimembranosus muscle was excised.

One lot was mechanically tenderized by passing the muscle three times through a Bettcher Industries Tend-R-Rite Model TR-2, at the slowest speed. Another lot was mechanically tenderized in like manner, and a solution consisting of 3.0% sodium tripolyphosphate (TPP) and 7.5% NaCl was pumped into the muscles to 10% of their weight. Pumping was done using a Koch Tenderizer Injecter (8127) equipped with four stainless steel needles 2.2 cm apart. A constant pump gauge pressure of 13.6 kg was maintained during pumping. The third lot received no mechanical tenderization, but was pumped with the TPP-NaCl to 10% of their raw weight. The fourth lot received no mechanical tenderization and no phosphate or salt solution. The treated roasts (semimembranosus muscles) were frozen to a temperature of –23°C and 5 slices 1.27 cm thick were obtained from the center portion of each roast by cutting across the grain with a meat saw. A 6.35 cm diameter die was used to cut individual steaks from the slices in each treatment. All steaks were grilled at a temperature of 176°C for 3 min per side. The grilled steaks were frozen at –23°C prior to dehydration in a Stokes freeze dehydrator at a plate temperature of 51.6°C and a chamber pressure of 0.3–0.5 mm Hg (0.047–0.067 k Pa). All treatments were sealed with a nitrogen flush in No. 2-1/2 cans and stored for one month.

After storage, the steaks were rehydrated in 48.9°C water for 10 minutes and rehydration percentages were determined by weight difference. Penetration measurement of tenderness was accomplished according to the method of Hinnergardt and Tuomy (1970) using an Allo-Kramer shear press modified with a five-needle penetrometer head. The trim from each raw steak was composited for each treatment and analyzed for % moisture, % fat, % NaCl, P mg/100g, % Ash, pH and % protein by Official AOAC (1970) methods.

Immediately following the needle penetrometer measurement, each steak was submitted to subjective evaluations. The subjective attributes evaluated were cutability, tenderness, juiciness and residue. A nine-category bipolar type scale was used to estimate the magnitude of each attribute. Judges were 20 food technologists and food chemists selected on the basis of previous experience in the sensory assessment of food texture, including meats. Two replications of the experiment were conducted: one in the morning and the other the afternoon of the same day. Samples were presented in a balanced random order. Judges were given an instruction sheet containing definitions of each attribute and criteria for making judgments.

Table 2–Variance of the Allo-Kramer penetrometer data for grilled, freeze-dried steaks with and w/o mechanical tenderization, and with and w/o a solution of PO_4 and NaCl

Treatments[a]	Variance
Control (no mechanical tenderization or PO_4 and NaCl	4.24
PO_4 and NaCl solution only	4.24
Mechanical tenderization only	1.44
Mechanical tenderization plus PO_4 and NaCl	0.90

[a] N = 40 observations/treatment. Five slices were selected from the center portion of each roast and there were eight roasts per treatment.

Table 3–Chemical analysis of raw steaks treated with and w/o mechanical tenderization and with and w/o a solution containing P and NaCl[a]

Treatments	H_2O	Fat	NaCl	P (mg/100g)	Ash	pH	Protein
No mechanical tenderization or PO_4 and NaCl solution	70.77	5.44	0.19	210	1.06	5.4	21.97
PO_4 and NaCl solution only	73.56	2.28	0.84	248	2.06	5.5	20.74
Mechanical tenderization only	71.69	3.98	0.23	217	1.11	5.3	23.46
Mechanical tenderization and PO_4 and NaCl solution	73.45	4.72	1.14	275	2.28	5.7	19.62

[a] Solution concentrations were calculated on a weight/weight basis of tripolyphosphate, NaCl and H_2O. The analysis reports elemental phosphorus and % NaCl found in the samples.

RESULTS & DISCUSSION

MECHANICAL tenderization of USDA Choice top rounds prior to cutting into 1.27 cm thick steaks resulted in grilled, freeze-dried steaks that were significantly more tender than the control as well as those samples that were injected with TPP-NACl solution. When considering those steaks that were mechanically tenderized, it should be noted in Table 1 that their tenderness was significantly superior to the treatments that were not mechanically tenderized. The penetrometer results in Table 1 also reflected the differences in tenderness found by the sensory panel, and these results agree with one another. It is also interesting to note that the steaks which were mechanically tenderized had less residue than the steaks that were not mechanically tenderized. Mechanical tenderization in the authors' opinion produced a freeze-dried steak which resembled a normal steak in appearance and texture.

Another effect of mechanical tenderization can be noted in Table 2. Comparison of the variances by means of an "F" test reveals that mechanical tenderization resulted in highly significant ($P < 0.01$) reduction in the variation of the tenderness of rehydrated, grilled, freeze-dried beef steaks. This resulting increase in uniformity of tenderness of the freeze-dried steaks should add greatly to their acceptability. Mechanical tenderization accounted for 69% of the variance components when tenderness was measured by the penetrometer and 40% as measured by the sensory tenderness panel. The TPP-NaCl solution had a small but significant effect on the tenderness of the freeze-dried steaks. The solution accounted for 8.9 and 12.2% of the variability components of tenderness for the penetrometer and taste panel evaluation respectively, as calculated by the method of Hicks (1956). The sensory attribute of cutability did not reflect the difference between addition or nonaddition of the TPP-NaCl solution to the mechanically tenderized samples.

The TPP-NaCl solution treatment had the most notable effect on sensory juiciness and percent rehydration of the grilled freeze-dried steaks (Table 1). A two-way analysis of variance showed the injected solution and not mechanical tenderization alone to be the responsible factor for the difference in juiciness. Table 1 does not indicate a clear difference between the treatment of mechanical tenderization and the treatment of mechanical tenderization with the injected phosphate solution due to the one-way analysis of variance and the multiple range test used to separate the means. Even though this difference failed to be statistically significant, the panelists rated the solution-injected samples higher in juiciness than the noninjected samples. The higher tenderness ratings for the TPP-NaCl injected samples over the control samples probably resulted from the improved rehydration and juiciness observed for the phosphate-salt treated samples.

The phosphate-salt solution contributed a significant (16%) of the variance component of rehydration. Mechanical tenderization also significantly effected rehydration, but contributed only 4.4% to the variance components of rehydration. Another 7% of the variance was attributable to the interaction between the injected solution and the mechanical tenderization treatment.

The chemical analysis reported in Table 3, reflected the changes in moisture, NaCl, P, ash, pH, fat and protein caused by the injected solution. Injection of the solution increased moisture content, NaCl, P, ash and pH. Undoubtedly, most of the difference in NaCl, P and pH between the steaks with TPP-NaCl solution only and those with mechanical tenderization plus the solution was due to the problem of achieving a uniform injection, even though the raw roasts were allowed to equilibrate at 4.4°C for 2 hr before freezing, slicing, cooking and dehydration.

It was concluded that while addition of TPP-NaCl solutions improved the texture of freeze-dried steaks, the most satisfactory textural quality resulted from mechanically tenderizing the roast and then injecting with TPP-NaCl solution.

REFERENCE

AOAC. 1970. "Official Methods of Analysis," 11th ed. Association of Official Agricultural Chemists, Washington, D.C.

Bird, K. 1965. Palatability of freeze-dried meats. Food Technol. 19: 737.

Bouton, P.E., Carroll, F.D., Fisher, A.L., Harris, P.V. and Shorthose, W.R. 1973. Effect of altering ultimate pH on bovine muscle tenderness. J. Food Sci. 38: 816.

Hamdy, M.K., Cahill, V.R. and Deatherage, F.E. 1959. Some observations on the modifications of freeze-dehydrated meat. Food Research 24: 79.

Hicks, C.R. 1956. Fundamentals of analysis of variance. Part 2. The components of variance and the mixed model. Ind. Qual. Control 13: 5.

Hinnergardt, L.C. and Burger, G.T. 1975. The effect of selected roasting parameters on the acceptability of cooked sliced, freeze-dried beef. J. Food Sci. In Press.

Hinnergardt, L.C. and Tuomy, J.M. 1970. A penetrometer test to measure meat tenderness. J. Food Sci. 35: 312.

Penny, I.F., Voyle, C.A. and Lawrie, R.A. 1963. A comparison of freeze-dried beef muscles of high or low ultimate pH. J. Sci. Food Agric. 14: 535.

Shults, G.W., Russell, D.R. and Wierbicki, E. 1972. Effect of condensed phosphates on pH, swelling and water-holding capacity of beef. J. Food Sci. 37: 860.

Tuomy, J.M., Lechnir, R.J. and Miller, T. 1963. Effect of cooking temperature and time on the tenderness of beef. Food Technol. 17: 1457.

Wismer-Pedersen, J. 1965. Effect of EDTA and pH on properties of freeze-dried pork muscle. 2. Effect of injection of EDTA and NaOH before drying. J. Food Sci. 30: 91.

Ms received 8/28/74; revised 11/12/74; accepted 11/17/74.

The use of trade names does not represent an endorsement of the product by the Dept. of Defense.