HYDRODYNE-TREATED BEEF: TENDERNESS AND MUSCLE ULTRASTRUCTURE

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INTRODUCTION

Tenderness is considered to be one of the most important sensory characteristic of meat. Solving the problem of inconsistent meat tenderness is a top priority of the meat industry. An extensive amount of research during the past 50 years has been devoted to improving tenderness of meat. A variety of techniques which include mechanical, chemical, conditioning, aging, electrical stimulation, altered carcass positioning have been introduced for tenderizing meat. MacFarlane (1973) and Bouton et al. (1977) pioneered the use of high hydrostatic pressure to tenderize meta either in the pre-rigor or post-rigor state. Hydrostatic pressure is the process of compressing the water surrounding the food item in a pressure vessel by pumping more fluid into the closed vessel. These authors found that shear values of pre-rigor meat subjected to hydrostatic pressure of about 150 MPa were lower than for non-pressurized control muscle tissue.

Hydrodyne®, a relatively new process for improving meat tenderness (Solomon et al., 1997), uses a small amount of high energy explosive to generate a hydrodynamic-shock wave in liquid medium (water). The shock wave passes through objects in the water that has a mechanical impedance mismatch with it. Meat, which is approximately 75% water in composition, is a close mechanical impedance-acoustical match (Kolsky, 1980). Results suggest positive and instantaneous tenderization of fresh meat using the Hydrodyne process (Solomon et al., 1997). In view of the effects of the Hydrodyne process on meat tenderness, we examined the ultrastructure of muscle to determine whether the effects of hydrodynamic pressure can be detected.

Materials & Methods

In the Hydrodyne process described in these experiments, all meat was first vacuum packaged with plastic bags followed by a rubber vacuum package. In this study 208 liter plastic containers, 51 cm in diameter, situated below ground level were used to contain the force of the explosion. The packaged meat was placed on the bottom of the container against a 2 cm thick steel plate. The explosive was submerged in the water to a distance of 38 cm away from the interface of the steel plate. Meat portions treated with the Hydrodyne process were subjected to 100 g of explosive which generated a hydrodynamic pressure of about 100-130 MPa at the point of contact with the meat surface.

Study I: Four matched pairs of 3-days postslaughter (PM) 'Choice' grade boneless beef strip loins (longissimus muscle = LM) were equally divided into the following treatments: control-3-d PM, Hydrodyne-3-d PM, aged-17-d PM, aged-21-d PM, aged-28-d PM, and aged-35-d PM.

Study II: Beef boneless strip loins (USDA 'Select'- 5-d PM) were cut into portions with the rib end and loin end randomly assigned to either the Hydrodyne treatment or control to minimize location effect. Muscle samples (3 x 1 x 1 mm) were removed from the treated and control muscles (within 30 minutes) after Hydrodyne treatment and were prepared according to the method described by Wergin and Endo (1976) for transmission electron microscopy evaluation.

Shear-force: In both studies steaks were cut (3.2 cm in thickness) from each section of LM representing either control, Hydrodyne or PM aging treatment. Two steaks from each loin section representing each treatment group were used for shear-force evaluations. Each steak was broiled, according to the methods described in the 1995 American Meat Science Association cookery and evaluation guidelines, to an internal temperature of 71 C using Farberware Open Hearth broilers (Model 350A). Six to eight cores (1.27 cm diameter each) were removed, parallel to the muscle-fiber orientation, from each steak after cooling to room temperature (~25C). Shear-force was determined using a Warner-Bratzler shear device mounted on a Food Texture Corp. texture measurement system (Model TMS-90).

Statistics: In study I data were analyzed using analysis of variance and F-tests (SAS, 1995) to determined significance of variation. Least-squares means and linear contrasts were generated. The Duncan's Multiple Range test was used to compare treatments at the .01 level. In study II the paired t-test procedure was used to determine if the means of the shear values for the Hydrodyned treated samples were significantly different from the controls.

Results & Discussion

Study I: Aging reduced shear-force by as much as 37% in the aged-17-d PM samples and as little as 24% in the aged-28-d PM treatment group compared to controls (Table 1). There were no statistical differences ($P > .01$) among the different aging periods; all aging periods decreased ($P < .01$) shear values. The Hydrodyne process, which was performed at 3-days PM, improved shear-force 33%, which was equivalent in effectiveness in tenderizing as those found for the four aging periods evaluated. Tenderizing meat with the Hydrodyne process results in instantaneous tenderness eliminating the need to age meat postmortem which would result in major energy (refrigeration costs) savings.

Study II: Shear-force for the steaks representing the Hydrodyned samples was 3.4 ± .6 kg which was 37% less ($P < .01$) than the shear-force for the controls which was 5.4± 1.4 kg (Table 1). The mechanism by which the Hydrodyne process increases tenderness in muscle instantaneously may be explained by ultrastructural observations of the myofibrillar and associated proteins (Figure 1). The structure of 5-d PM, LM for control (Figure 1A) and Hydrodyned (Figure 1B) samples are shown in Figure 1. Figure 1A shows the morphology that is typical of 5-d PM muscle. Longitudinal sections clearly show virtually no disruption of myofibrils near and within Z-line regions. No I-band fractures adjacent to the Z-line were observed. Evaluation of the Hydrodyned tissue show disruptions of myofibrils near and within the Z-line regions of the sarcomeres. The disintegrity of the I-band adjacent to Z-lines resulted in Z-line protein material being torn and remnants attached on either side of the fractures. Further evaluation of muscle exposed to the hydrodynamic pressure exhibited clearer, straighter and more distinct M-lines than in the controls. It might be that friction and/or coagulation of elastic filaments (like titin) caused the clearer appearance of the M-lines after Hydrodyne treatment. These observations are different from the appearances typically seen after applying other techniques for tenderizing meat. For example, both Ouali (1990) and Goll et al. (1983), reported slow loss of M-line structure during postmortem aging through 13-d PM at a temperature of 16C with no signs of damage in the A-band or I-band regions. It was the junctions between the two regions that was disrupted during the aging period.

A recent ultrastructural report by Ho et al. (1996) from electrically stimulated muscle samples using 200 V, 20 HZ for 15 seconds illustrated increased spaces between Z-lines of adjacent myofibrils and I-band fractures adjacent to the Z-lines. However, Z-lines remained attached to the thin filaments on at least one side of the fracture. Only after 28-d post-stimulation, 2 to 5 small gaps were evident near a typical Z-line. In studies where hydrostatic pressure was applied to beef semimembranosus muscle at 150 MPa (for 3 h at 0C) the absence of M-lines and more disorganized I-band proteins with an aggregated appearance were observed. Z-lines, after applying hydrostatic pressure, were intact with no major fractures.

In summary, ultrastructural alterations in bovine LM were observed after the Hydrodyne treatment. Physical disruptions occurring in I-band adjacent to the Z-lines and increased frequency of longitudinal spaces between filaments, in the A-bands of myofibrils in Hydrodyned samples, were observed within less than 30 minutes after applying the Hydrodyne process. This process must have a substantial weakening effect on the structure of the muscle and could be one of the major causes of the observed tenderizing effects seen in Hydrodyned samples.

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Table 1 - Shear-force values of beef strip loin steaks from control, Hydrodyne or postmortem aging treatments

	Control	Hydrodyne	Aged-17d	Aged-21d	Aged-28d	Aged-35d	SD
Study I -USDA Choice							
Shear-force, kg	4.75[a]	3.17[b]	3.01[b]	3.50[b]	3.59[b]	3.15[b]	0.7
Study II - USDA Select							
Shear-force, kg	5.4[a]	3.4[b]					1.0

[ab] P<.01.

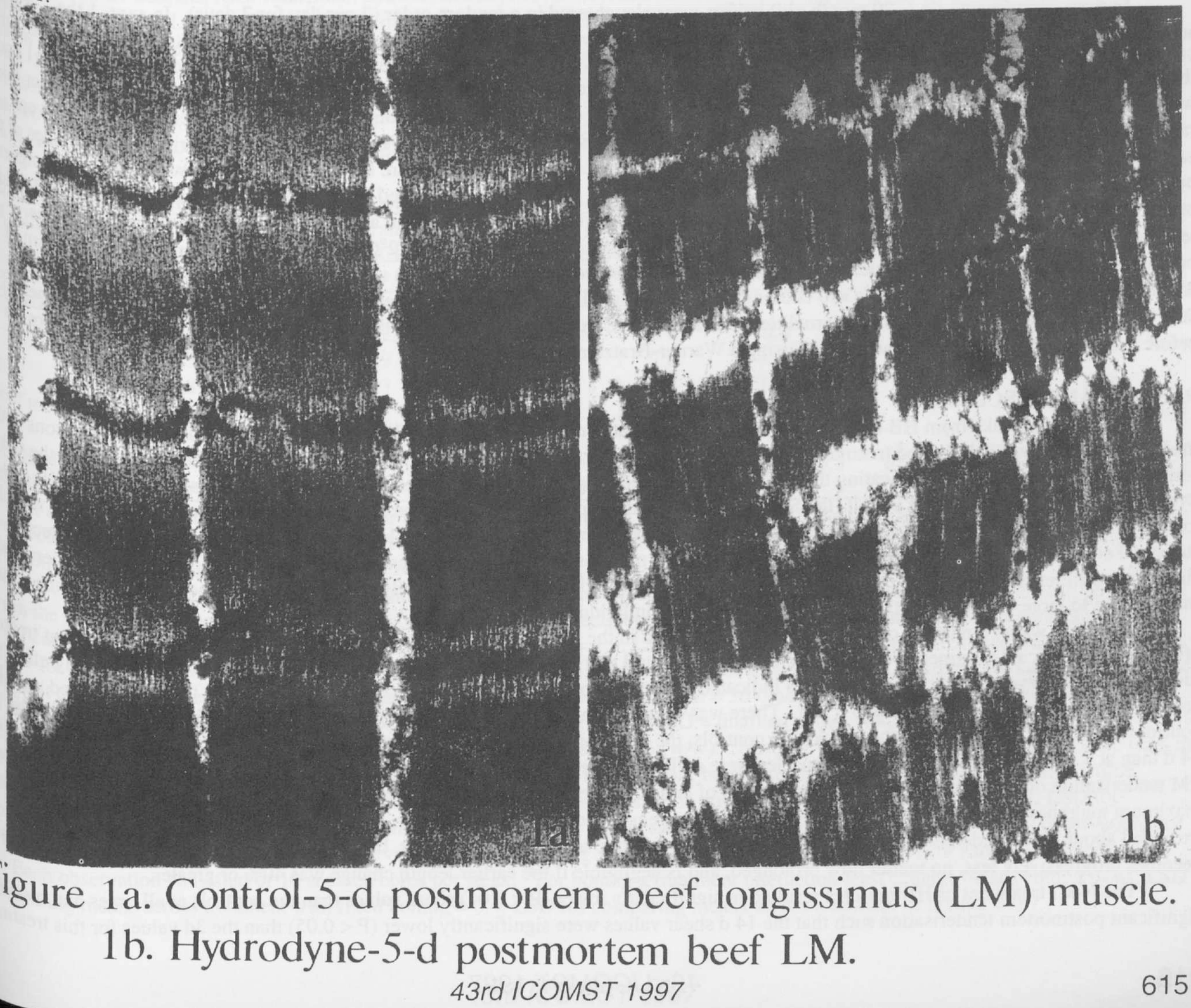

Figure 1a. Control-5-d postmortem beef longissimus (LM) muscle.
1b. Hydrodyne-5-d postmortem beef LM.