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Addressing the Beef Tenderness Problem

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INTRODUCTION

We've all heard time and again the importance of beef tenderness to customer satisfaction. Research continually supports this concept. In the Beef Customer Satisfaction report from the National Cattlemen's Beef Association, tenderness was highly correlated to consumer ratings of their satisfaction with the product (r=.85), as was flavor desirability (r=.86). Recent focus group participants in a session discussing beef quality were quick to identify tenderness as one of the primary descriptors to quality. There is no doubt that tenderness is a critical characteristic of beef and providing product which does not meet consumer expectations will definitely reduce satisfaction with the eating experience.

Strategies are needed to enhance tenderness. However, several philosophical or conceptual questions must be addressed before we as an industry pursue particular methods and technologies to meet the desired goal.

DO WE NEED IMPROVED CONSISTENCY OR ENHANCED TENDERNESS?

This is a significant question. It's my feeling that the extent of consumer satisfaction with beef depends to a large extent on their expectations. A steak from the grill or one purchased in a white tablecloth restaurant presents different expectations than one purchased at a reduced price in an economy store. The retail market is replete with examples of products which demonstrate that consumers are willing to make judgements on value based on costs versus expected product attributes. That's why there's a consumer market for steaks that range in tenderness, like round steak, top sirloin steak, and tenderloin steak.

To improve consistency, we simply need to better sort the products we have. Koohmaraie and his colleagues at the U.S. Meat Animal Research Center have conceived and constructed an on-line instrument capable of measuring tenderness for a chilled beef carcass. Direct measurement of tenderness avoids the problems associated with using indicators to predict expected tenderness. The approach definitely offers the opportunity to sort carcasses into tenderness categories.

Given that management systems to assure meat tenderness are not well understood, not everyone is willing to accept tenderness measurement as a way to determine carcass value. The next presentation might offer some insights into how this might be accomplished.

Some might suggest we simply need to use genetics to enhance tenderness of all beef and the problem will be solved. We need to understand that biological variation will always exist and even if it were possible to enhance tenderness genetically, there would still be cattle in the population whose meat is marginally acceptable or unacceptable in tenderness.

Judging by the variety of current activities, one might conclude that both strategies are needed. That is, we need to enhance tenderness and do a better job of sorting beef on the basis of tenderness. Such an approach means we need the tools to sort and tools to genetically select for tenderness. A third tool would be to alter or manipulate the tenderness of meat.

WHERE IS THE BEST PLACE IN THE PRODUCTION-TO-CONSUMER CHAIN TO ALTER TENDERNESS?

Genetic selection or screening represents application of powerful laboratory techniques for solution of a complex industry problem. We must be realistic, however, about the potential use of such a tool. Given the number of producers that have relatively small numbers of cows is it realistic to believe that knowledge of the genetic potential for an animal to produce tender meat will be used to make a meaningful shift in the population of animals available for market? Granted, large commercial producers could make good use of such information. Wouldn't a fair proportion of cattlemen be unable or unwilling to rigorously apply selection pressure to change the overall industry average and enhance meat tenderness? I do not mean to imply that genetic selection be abandoned - indeed, there are some promising data coming forward which suggests that progress can in fact be made. Rather, I would proposed that this alone will not solve the problem. Especially when tenderness can be influenced by such a large extent during and after the slaughter process.

Perhaps a better target area to alter tenderness is in the feedlot. Special feed ingredients like vitamin D (studied by Texas Tech University and Oklahoma State University) which appear to enhance tenderness would be welcome additions to the arsenal. Again one must ask - will all feeders pay the additional cost to improve the product or will the partial adoption of such a technology contribute to even greater variation in quality and tenderness?

A third approach might be to improve the product at the packing plant . Given the diversity in production and feeding, application of a technology in plants might be best place to uniformly apply it to all of the cattle. No doubt variation exists in handling practices at the various plants. But in many ways, packing plants become the funnel through which all of our cattle must pass on their way to the ultimate consumer.

COMPONENTS OF TENDERNESS

Many of you are familiar with the primary components of tenderness. That is, the contribution of muscle fibers and connective tissue. It's of use to briefly review them again here as an introduction to technology which might alter their relative contribution to the ultimate tenderness of beef.

<u>Muscle</u> <u>Fibers</u> - muscles are composed of cells which contain overlapping protein filaments. The extent to which these filaments overlap is an indication of the degree contraction. Logic

suggests, and research supports, the notion that more contracted muscles are less tender. Therefore, anything we can do to minimize the degree of contraction within a muscle or to disrupt the structural integrity of the fibers, the more tender the muscle. This opens up many strategies that have been investigated to improve tenderness. Aging, for example, allows calcium-dependent enzymes (called calpains) to break down proteins and thus enhance tenderness. Addition of calcium chloride has been successfully added to muscle to increase calpain activity and thereby improve tenderness. Electrical stimulation creates micro-tears in the muscle structure and also appear to enhance proteolysis. Together these tools offer opportunities to improve tenderness of muscle fibers.

Unfortunately, the degree of contraction can be profoundly influenced by conditions after slaughter. Muscles subjected to very cold temperatures prior to entering rigor mortis, the stiffening process that occurs after death, shorten and become less tender. The cooler temperatures also reduce calpain enzyme activity. As a result, these "cold shortened" muscles are much less tender than normal.

<u>Connective</u> <u>Tissue</u> - Muscles, as well as muscle cells, are surrounded by connective tissue. This dense, tough tissue is primarily comprised of a fibrous protein called collagen. The more active muscles used for locomotion (like those in the round and chuck) have more collagen and thus are less tender than muscles used primarily for support (loineye and ribeye).

As animals mature, the collagen protein becomes more cross-linked and less heat soluble. This causes older animals to be less tender than younger ones.

Because connective tissue exists in all muscle, it creates a background, or baseline, level of tenderness. Depending on animal age and muscle type, the relative contribution of connective tissue to tenderness can vary. One thing is certain, improvement in muscle fiber tenderness will only succeed to a certain extent, beyond which the connective contribution will limit progress. This means that it's not possible to make high connective muscles (like round steak) or muscles from older animals and make them taste like loineye muscles from young animals using strategies that only attack the muscle fibers.

HYDRODYNE

The Hydrodyne process offers considerable benefits to beef tenderness. The idea was conceived and patented by John Long of Hydrodyne, Inc. who then partnered with Dr. Morse Solomon of the USDA Meat Science Research Laboratory in Beltsville, MD to study the tenderness and commercial application of the process We were fortunate to be invited to participate in several studies on beef (Figure 1).

In the Hydrodyne process, a hydrodynamic shock wave is created in water through detonation of an explosive. Vacuum packaged meat is placed within the container with some type of steel behind it to reflect the shock wave. The pressures created by the passing and reflecting back of the shock wave are sufficient to create structural damage within the tissue and thereby improve tenderness. We also speculate that damage might occur to the organelle which contains calcium, thereby activating the calpains and enhancing the aging process. From a selection of studies, some conducted by the USDA and some by the University of Nebraska, a number of questions have been answered.

Early work was conducted within plastic barrels with a steel plate placed on the bottom. The shock wave occurs in milliseconds, meaning that the tenderizing effect occurs before the force ruptures the barrel. Recent research has been conducted at Tenderwave, Inc. in Buena Vista, VA in a commercially designed unit. It consists of a large, stainless steel bowl, 4-feet in diameter and 4-feet deep. Packaged meat is placed in the bottom of the bowl, immersed in water, and the explosive mixture is positioned above the meat. A bell-shaped lid is attached and the explosives are detonated.

Structural Damage

This electron micrograph (Figure 2) shows the structural damage which occurs to meat within the unit. Although no meaningful differences in the gross appearance of the meat is evident, these micro-tears within the muscle fiber mean that tenderness is improved. Zuckerman et al. (1997) were the first to demonstrate these effects to the muscle fiber.

Quantity of Explosive

The greater the quantity of explosive (a mixture of ammonium nitrate and nitromethane), the more pressure within the shock wave and the more tender the meat. Figures 3 and 4 demonstrate the improvement of tenderness observed with increasing amounts of explosive. The force which is applied to the meat depends on the proximity of the detonation to the meat as well as the quantity of explosive. The benefits of increased quantities of explosive were evident in both the smaller, test containers (Figure 3) and the larger, commercial unit (Figure 4).

Improvement in Tenderness

Table 1 presents results of Hydrodyne treatment for various types of muscle. Improvement in tenderness occurred in every experiment. The greatest change was a 66% reduction in shear force of beef longissimus muscle. It appears the benefits of treatment with the Hydrodyne process occur in muscles which are high in connective tissue as well as those that are not.

Flavor and Juiciness

No differences in flavor or juiciness were found in Hydrodyne-treated beef(Figure 5).

Aging versus Hydrodyne Treatment

Figure 6 demonstrates the effectiveness of the Hydrodyne process compared to aging. Select loins treated with Hydrodyne were as tender after shipping (7 d post mortem) as the controls were after 17 days of aging. O'Rourke et al. (1997a) have reported that treatment of pork chops with Hydrodyne 5 d post-mortem generated tenderness equal to control chops aged 40 days. At the completion of the aging period, there was no difference in tenderness of control chops aged 40 days and chops treated with Hydrodyne 5 days post-mortem. This suggests that there is a limit to which tenderness can be enhanced, either from aging or Hydrodyne treatment. We speculate that this is likely the threshold where the connective tissue component of tenderness becomes predominate.

For beef, Choice strip loins demonstrated a benefit to Hydrodyne treatment at 3 days of aging that was equivalent to 21 days of aging on the control (Figure 7).

Retail Stability

Treatment of beef did not compromise the rancidity development (Figure 8) of meat stored under retail conditions. O'Rourke et al. (1997b) also found no differences in purge during shipping or color ratings under retail display for Hydrodyne-treated beef.

Degree of Doneness

Steaks that are cooked to a higher degree of doneness are generally less tender. To be most effective, methods to enhance tenderness must succeed at different degrees of doneness. Figure 9 clearly demonstrates the tenderness benefit of the Hydrodyne process, even when meat is cooked well done.

CONCLUSION

The Hydrodyne process offers considerable opportunities to enhance beef tenderness, even in muscles with high connective tissue content. It's easy to imagine an operating model whereby a Hydrodyne facility is built at or near beef packing plants, making the technology available to a variety of products.

REFERENCES

Berry, B.W, Solomon, M.B., Johnson, W.L., Long, J.B., Eastridge, J.S., and Zuckerman, H. 1997. Application of the Hydrodyne process to strip loins from U.S. Select grade beef. J. Anim. Sci. 75(Supp. 1):128. (abstr.)

O'Rourke, B.M., Calkins, C.R., Rosario, R.T., Eastridge, J.S., Solomon, M.B., and Long, J.B. 1997a. Improvement of pork loin tenderness using the Hydrodyne process. J. Anim. Sci. 75 (Supp.1):53. (abstr.)

O'Rourke, B.M., Calkins, C.R., Rosario, R.T., Solomon, M.B., and Long, J.B. 1997b. Tenderness and retail stability of Hydrodyne-treated beef. Proceedings of the 50th Reciprocal Meat Conference, American Meat Science Association, Chicago, IL (In Press).

Solomon, M.B., Long, J.B., and Eastridge, J.S. 1997a. The Hydrodyne: A new process to improve beef tenderness. J. Anim. Sci. 75:1534-1537.

Solomon, M.B., Eastridge, J.S., and Long, J.B. 1997b. - The Hydrodyne process for tenderizing cold-shortened beef. Institute of Food Technol. Annual Mtg. #21-9, p. 50. (abstr.)

Solomon, M.B., Eastridge, J.S., Zuckerman, H., Long, J.B., and W. Johnson. 1997c. Hydrodyne-treated beef: Tenderness and muscle ultrastructure. 43rd Internat. Congress Meat Science and Technol., Vol. II.

Zuckerman, H., Solomon, M.B., and Long, J.B, 1997. Ultrastructural changes in bovine longissimus muscle by the Hydrodyne process. J. Anim. Sci. (In press)

Figure 1. Members of the Hydrodyne Beef Research Team

Hydrodyne, Inc.	Tenderwave, Inc
John B. Long Stanford Klapper	Eric Stanton
USDA-ARS-MSRL	*University of Nebraska*
Morse B. Solomon (Research Leader) Bradford W. Berry Janet S. Eastridge Hadasa Zuckerman Ernie W. Paroczay Marnie Bigner	Chris R. Calkins Bernadette M. O'Rourke Rose Marie T. Rosario Janet E. Hyde

Figure 2. Electron micrograph of Hydrodyne-treated beef loin muscle (Solomon et al, 1997c)

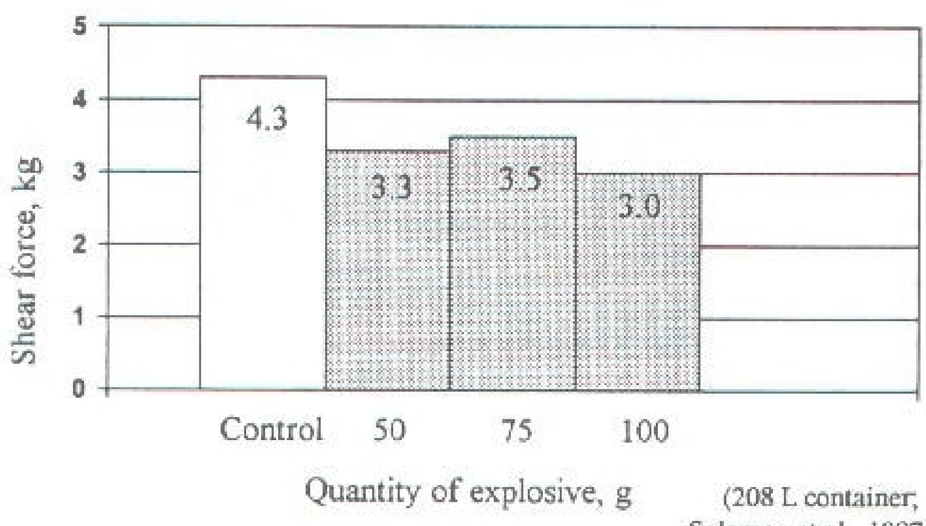
Table 1. Effect of the Hydrodyne process on tenderness of various beef muscles.

Muscle	Shear force, kg		Percentage
	Control	Hydrodyne	improvement
Longissimus	8.3[a]	2.8[b]	66.2
Semimembranosus	10.5[a]	4.3[b]	59.0
Biceps femoris	7.8[a]	3.7[b]	52.6
Semitendinosus	12.9[a]	5.7[b]	55.8

[a,b] Means in the same row with different superscripts are different ($P < .01$).

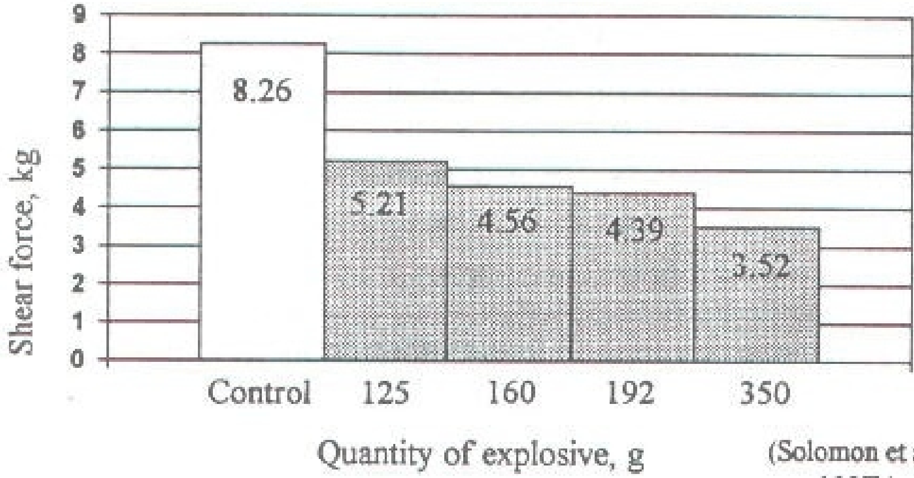
(Solomon et al., 1997a)

Figure 3. Quantity of explosive affects tenderization in the beef bottom round.



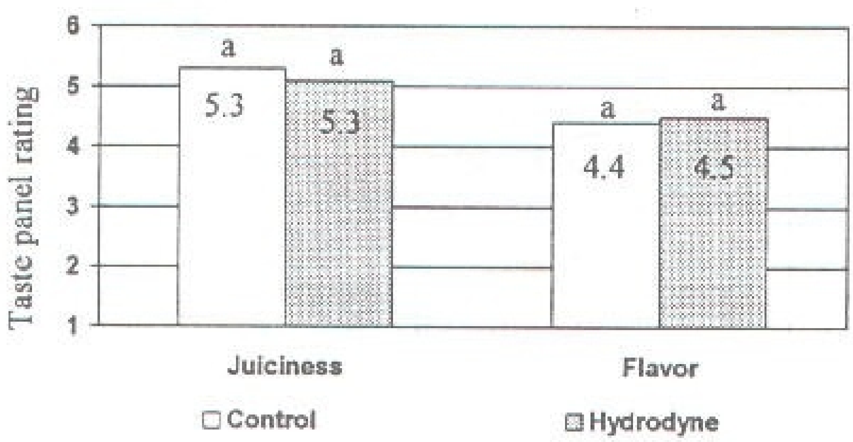
(208 L container; Solomon et al., 1997a).

Figure 4. Quantity of explosive affects tenderization of beef loins in the commercial unit.



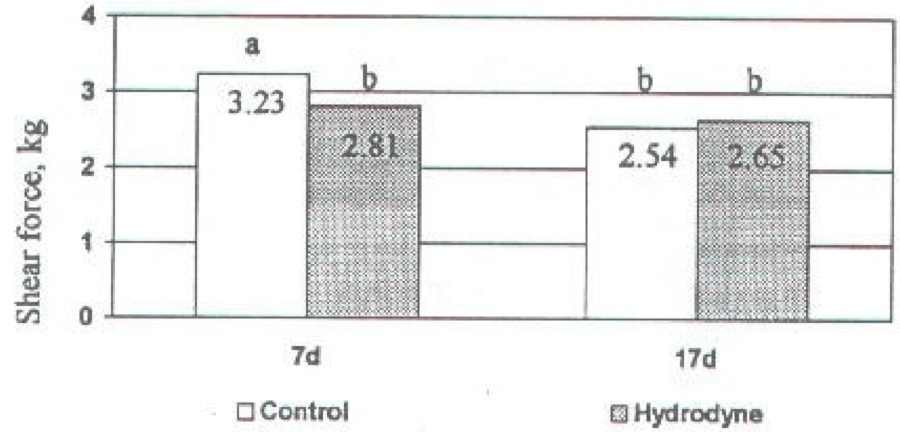
(Solomon et al., 1997b)

Figure 5. Flavor and juiciness of fresh 'Select' loin steaks treated with the Hydrodyne process.



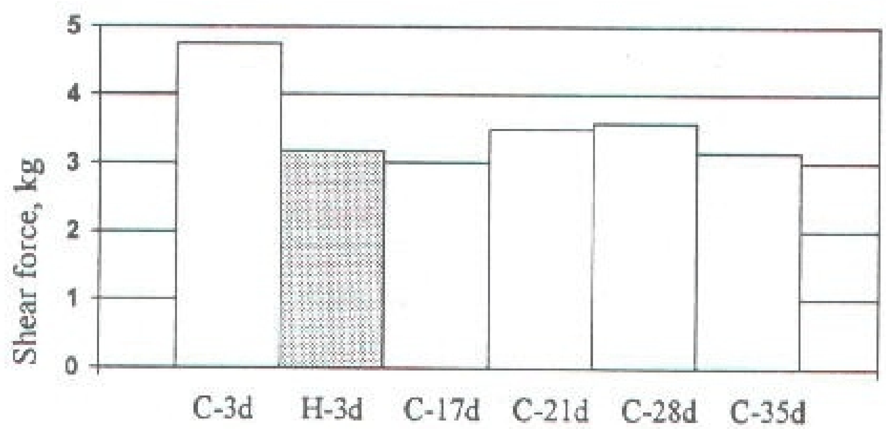
(Berry et al., 1997)

Figure 6. A comparison of aging and Hydrodyne treatment for 'Select' beef loins.



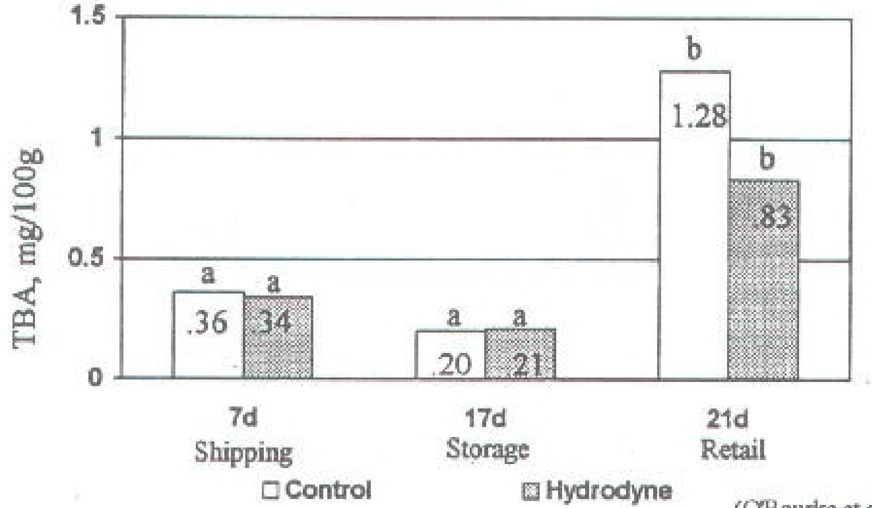
(O'Rourke et al., 1997b)

Figure 7. Beneficial effects of Hydrodyne versus Aging of 'Choice' Beef Loins.



(100g, 28 cm, 208 L container ;
Solomon et al., 1997c)

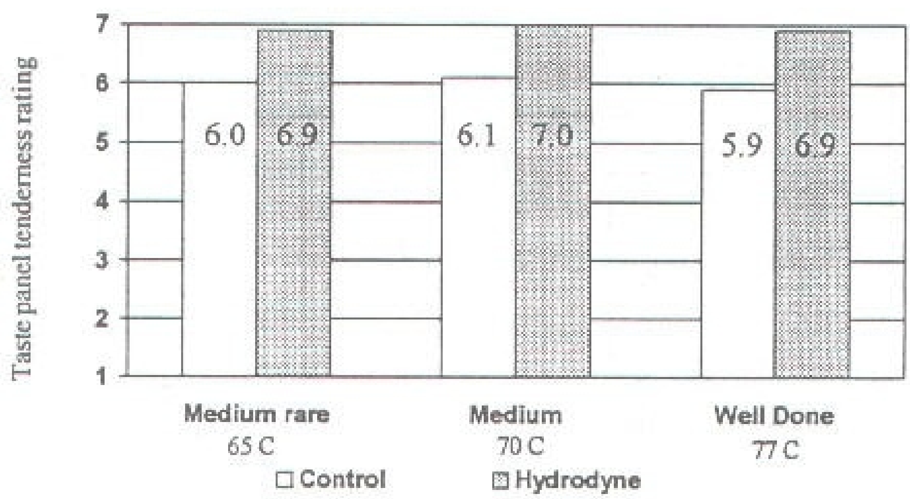
Figure 8. Oxidative rancidity (measured as thiobarbituric acid reactive substances) of Hydrodyne - treated beef loins during storage, shipping, and retail display.



P < .05

(O'Rourke et al., 1997b)

Figure 9. Benefits of Hydrodyne to tenderness of 'Select' beef loins at various degrees of doneness.



(Berry et al., 1997)