Ka-Boom!

A shockingly unconventional meat tenderizer

By JANET RALOFF

People often laugh—or at least snicker—when John B. Long starts regaling them with details of his latest venture: explosions to tenderize beef, lamb, or chicken. The usual reaction is that it's overkill.

Morse B. Solomon confesses to having reacted with equal parts of surprise and disbelief 6 years ago, when he first encountered Long and his partner, Stanford Klapper. As head of meat science studies at the Department of Agriculture's Beltsville Agricultural Research Center near Washington, D.C., Solomon received a request from the Secretary of Agriculture's office to listen to this pair detail their newly patented process for split-second rendering of even tough chuck into something as tender as prime tenderloin.

In the past, Solomon had investigated some unconventional approaches to tenderizing meat, from electric stimulation (SN: 12/9/78, p. 409), which worked, to bombarding meat with ultrasound, which didn't. So he was prepared to keep an open mind as Long described the process: Set off an explosion in a tank of water, and let the resulting shock waves rip through meat at the bottom of the tank.

When their presentation left Solomon dubious, Long and Klapper invited him to witness a field test. Though that test failed miserably, Solomon says, subsequent ones proved spectacularly successful—turning him into a believer and his agency into a research partner of Long and Klapper's firm, Hydrodyne, in San Juan, Puerto Rico.

Some $1.2 million worth of studies later, experiments with this technology account for 80 percent of the activities of Solomon's lab. "There's no one here who doesn't think this technology shows exciting promise," he told SCIENCE NEWS. In fact, he maintains, it "hasn't met a piece of meat it doesn't like."

Long, now 78, gushes with similar enthusiasm over the prospects for this process, known as Hydrodyning. Last August, his company signed up the Houston-based Brown & Root, a subsidiary of Halliburton Co., to commercialize the technology. The goal is to build and operate Hydrodyning facilities, perhaps as adjuncts to slaughterhouses or meat-packing plants.

Solomon has also discovered that the explosive shock waves can kill germs. He suspects the process may rupture the membranes that encase bacteria. Moreover, studies by the Beltsville group have shown that the shock waves can kill the parasites in pork responsible for trichinosis. What these early studies haven't determined is whether forces strong enough to kill the bacteria and parasites would turn steaks to mush.

The idea of bombing meat came to Long some 30 years ago, while he was floating in his backyard pool. A mechanical engineer at Lawrence Livermore (Calif.) National Laboratory, he worked as an explosives expert on the design of triggering mechanisms for nuclear weapons. He was very familiar with conventional explosives and the shock waves created when they go off.

"My body has about the same density as the water," he observed, "so if somebody threw a bomb into my pool, the shock waves should go right through me." He started thinking about what those shock waves might do to his muscle—or to a piece of steak. To find out, he recruited friends for an experiment at a privately owned explosives testing site a few miles away.

They sliced a piece of tough beef in two, bagged half of it in plastic, and dropped it into the bottom of a 50-gallon paperboard drum of water. Then they suspended conventional explosives in the water and retired to a nearby bunker. From there, they watched in safety as a television displayed the ensuing detonation.

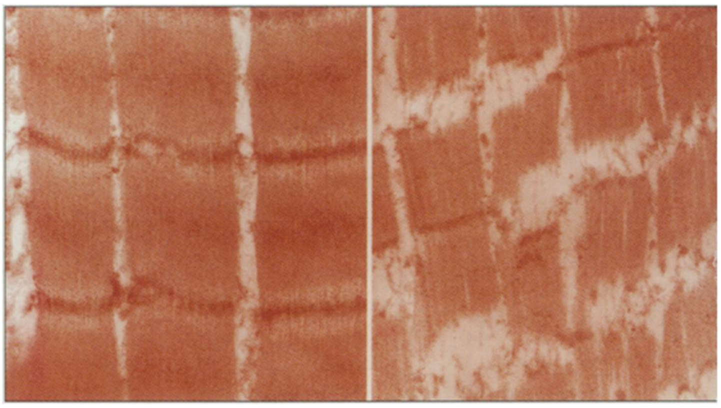
"The drum totally disappeared. There were just little pieces of paper fiber all over," Long recalls. The meat, ejected to the side of a nearby hill, was missing for fully 15 minutes.

Once the treated meat had been retrieved, Long cooked it, along with its untreated counterpart, on a grill he had lugged to the site. The unshocked meat proved "so tough you could hardly chew it," Long says. "But the one we shocked—it was delightful, as tender as a $10 steak in those days."

Unsure what to do next, Long shelved the technology for 20 years. In 1988, retired and living in Sarasota, Fla., Long teamed up with Klapper, a marketing specialist, to make low-cost solar cookers. As soon as Klapper heard about Long's meat exploits, he suggested they incorporate to develop the novel tenderizing technology.

While Long ultimately planned to build rugged steel detonation chambers, until 2 years ago he used $6 plastic garbage cans. Despite their crude appearance and the fact that they are destroyed in each detonation, garbage cans work like a charm, Solomon says—as long as they have a shock-wave reflector, such as a 3/4-inch-thick metal disk, covering the bottom. The garbage can is placed in a hole in the ground so that the meat can be retrieved easily.

"It took me about 2 years to figure out how much explosive we needed"—typically 100 grams or so—"and where it needed to be placed," Solomon says. Like a boy playing with caps on a deserted road, he says, the studies proved "unbelievable fun."



Zuckerman/Journal of Muscle Foods

Electron micrographs of beef muscle 5 days after slaughter. Untreated meat (left) shows intact dark horizontal bands (Z lines). Shock waves ruptured many of these in treated muscle (right). Moreover, in untreated meat, the A bands—strong, square patches of muscle bordered by Z lines and long, vertical white bands—remain intact. The A bands show numerous small tears (thin, vertical white streaks) after treatment with explosive shock waves.

They also yielded impressive results.

Tenderness is typically measured in kilograms of force needed for a guillotinelike steel blade to slice through a core of cooked meat, explains Janet Eastridge, who works with Solomon. As a rule, 4.6 kilograms tends to be the dividing point. Meat requiring less force to cut is reliably tender, whereas meat needing higher shear forces—which can exceed 15 kilograms—ranges from chewy to downright leathery.

With the shock-wave treatment, Solomon says, "I can bring meat that starts with a shear force of 6, 8, or 12 kg down to 3 or 4 every time—sometimes even lower." For perspective, he notes, well-aged cuts of meat may have a shear force of around 3 kg, and a little below that matches a filet mignon.

To understand what's happening, Hadasa Zuckerman, also a colleague of Solomon's, has been using transmission electron microscopy to analyze treated meat. When magnified about 4,000 times, muscle fibers show several characteristic patterns of striations. In the fraction of a second it takes the shock waves to pass through the meat, some of these structural bands rip.

More conventional tenderizing processes, such as aging and chemical treatment, digest dark segments known as Z lines until they disappear. Shockwaved Z lines merely fragment and break their ties to adjacent tissue. Rupturing 60 percent of the Z lines—as the shockwave process typically does—results in measurable tenderization, Zuckerman says.

Perhaps even more important is a unique pattern of tiny rips that occurs in the strongest portion of the muscle fabric, known as the A band. "You need a tearing in only 20 percent of the A bands to get a tenderization," Zuckerman says, and Hydrodyne's treatment may induce rips in 80 percent of them.

Her findings, slated to appear later this year in the JOURNAL OF MUSCLE FOODS, also appear to explain why meat from some geriatric animals isn't as susceptible to tenderizing with shock waves as the muscle of younger ones. As they age, livestock develop more connective tissue binding the muscle fibers together. This connective tissue appears fairly resistant to shock-wave shearing—at least at the pressures now being tested.

Because the Beltsville muscle studies indicate that not all meats respond identically to the shock waves, commercial operations may have to segregate types or cuts of meat and tailor the explosive power delivered to each. Indeed, tenderizing chicken breasts needs pressures of up to 25,000 pounds per square inch—almost twice what other meats require.

Not quite 2 years ago, Long's company finally took delivery of what it hoped would prove a full-scale prototype of the tenderizer. In fact, the device is still evolving.

"Until recently, no one has tried to contain high explosives in a tank," Long explains. Even now, no one else is trying to do it in water, he maintains, "which is the toughest environment."

The system consists of a stainless steel tub 4 feet in diameter fitted inside a shock-absorbing frame. The device must withstand brief impulses of a million pounds of force. With few guidelines on how to repeatedly and reliably absorb such explosive energy, Long's team has had to remodel the shock-absorbing system several times to keep its braces from bending or its cushions from shattering.

S. Bauer/Agricultural Research magazine

Bradford Berry about to load vacuum-packaged meat into a basket that will be placed into the water-filled Hydrodyning tank in Buena Vista, Va. The tank is then covered with a baffled dome, in background, to keep water from splashing into the air during the explosion and to muffle sound.

While Long thinks he's finally engineered a fix, Solomon worries about another problem. The prototype works, but not as well as the garbage cans. Not only do its treated meats come out less tender than those in the garbage can, Solomon reports, but his team no longer sees the same consistency in tenderization within a batch of treated meats.

"So right now," he says, "we're all trying to figure out what parameters make the garbage can so good"—such as its geometry or shock-wave propagation dynamics. The fix should not prove insurmountable, Solomon and Long agree. They also concur that the payoff for finding it could be huge.

Each year, 37 million cattle are slaughtered in the United States for beef. Typically, wholesalers take up to 14 days to bring this meat to market. They could do it in perhaps 3 to 7 days if they weren't afraid the meat would be too tough, says Bradford W. Berry, another meat scientist on Solomon's team.

It takes a lot of energy to keep the meat refrigerated for a couple of weeks as it ages. If just half of the beef were treated with shock waves and brought to market in 1 week, Long has calculated, it could save 162 million kilowatt-hours of electricity annually, worth about $7.5 million at commercial rates. Moreover, the process would allow farmers to raise more grass-fed livestock—which yield leaner, tougher meat—thus dramatically reducing the demand for energy-intensive feed corn. These arguments won Hydrodyne a development grant from the Department of Energy.

While Uncle Sam won't earn a penny from the commercialization of the technology, the government may nonetheless derive substantial benefits from it. For instance, Berry is working with the Defense Department's research center in Natick, Mass., on using Hydrodyne's technique to improve the safety and palatability of foods for U.S. troops.

By law, the military must purchase the least expensive cuts of meat, which generally means the toughest. To make this meat stable for carrying into the field, much of it is subjected to processing technologies, such as freeze-drying, that risk toughening it further. The Army is interested in the shock-wave treatment, Berry says, "because they've got such a long way to go to make their products taste good." Currently, he's testing whether shock-wave tenderization will keep meats destined for freeze-drying from toughening unacceptably.

Long has a more personal interest in commercializing the technology. The swords-to-plowshares project represents "a way that I can give back something useful to humanity," he says—much like the solar cooker he designed years ago.

It also satisfies a lifelong need to design and build things. He's been that way since he was 8, he says. "That's when I got my first Erector set." □