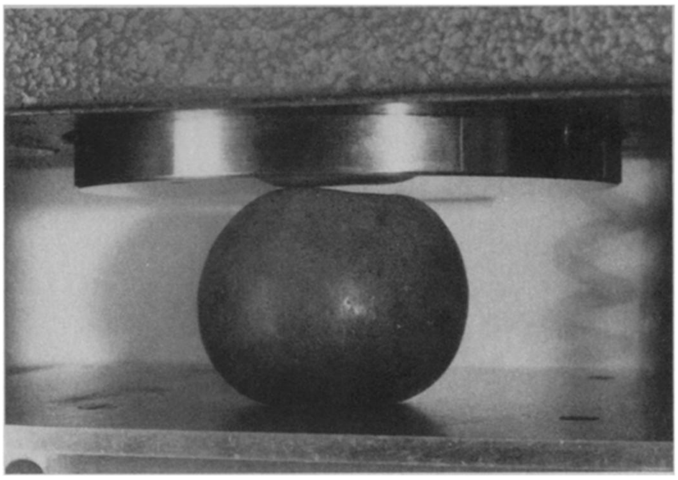
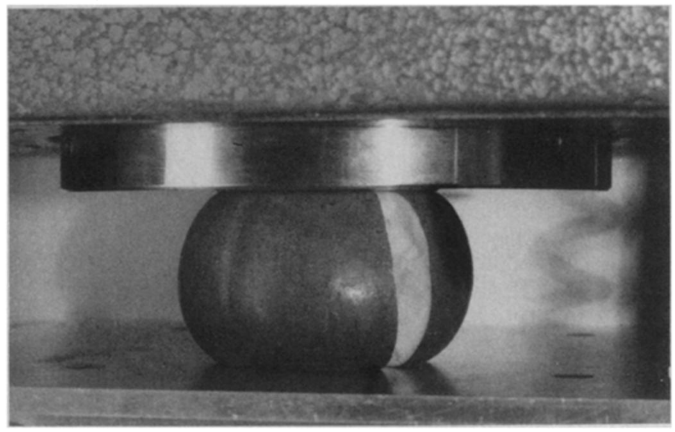


EVEN APPLES



An apple a day may keep the M.D. away, but apples keep a lot of Ph.Ds awfully busy

By STEFI WEISBURD

A goodly apple rotten at the heart.
O, what a goodly outside falsehood hath!
—Shakespeare, *The Merchant of Venice*

Go ahead. Take a bite out of that satin-skinned, crisp and juicy Rome Beauty.

Nothing would spoil that apple more than a bruise, brown and buried like a land mine, where the inner cells have ruptured. Luckily for applephiles, researchers are studying the mechanics of bruising as well as the overall textural properties of apples with an eye on improving apple quality and preventing bruises via better harvesting and handling.

Texture, many food scientists feel, has become as important as flavor and appearance in the consumer's selection of natural, processed and artificial foods. Food rheologists (scientists who study the deformation of foods) have devised techniques and tools — often borrowed from mechanical engineering — more precise and reproducible than a gourmet's palate to analyze the texture of apples and a supermenu of other foods as well.

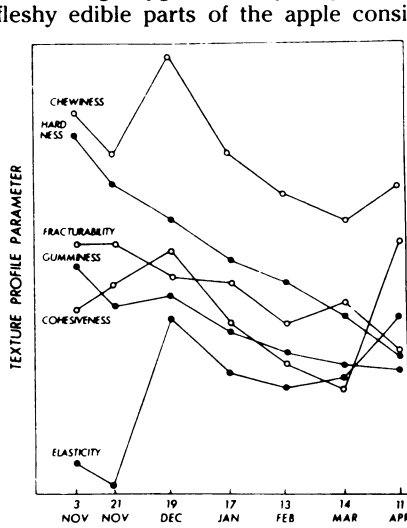
One of the scientists in the business of saving apples from bruises is M. G. Sharma (favorite apple—Delicious), a mechanical engineer at The Pennsylvania State University in University Park. Sharma machines his Rome Beauties with a jigsaw and lathe into three-quarter-inch cylindrical samples. A device, modified from one used to test the strength of plastics, is used to apply a controlled load to the sample, either by compressing or twisting it. By monitoring how the apple material responds, Sharma can predict the loading conditions that will cause the cell to rupture, creating a bruise. He used this information to formulate a computer model that simulates the distribution of stress and strain in a whole apple when it is subjected to forces like those found in packing crates.

Sharma checks the accuracy of his model by applying a specific load to a whole apple and then looking at the resulting strain pattern with holography. Where the fringes of the interference pattern are close together, he says, the strain is the greatest. This is where the bruise will occur. Sharma, who spends half his time on apples and half on the mechanical causes of cardiovascular disease, says he got the idea of using holography on apples because he had been using the technique to study damaged endothelial cells lining blood vessels.

In typical packaging and transport of apples, the fruits undergo a variety of different stresses and vibrations. If the apples are touching with a contact force of as little as a tenth of a pound, says Sharma, cells could rupture. He argues that the chances of this can be diminished by increasing the area, through proper packing, over which the force acts. The cushions of air found in Styrofoam and other polymeric materials, for example, carry and distribute the force over the surface of the apple.

In addition to bruising, growers and grocers are concerned about the effects of growing conditions and storage on the quality of apples. According to Malcolm Bourne (who favors Delicious and Empire), a food scientist at a branch of Cornell University in Geneva, N.Y., numerous studies have been done that measure the firmness of apples as a function of fertilizers used, size of fruit, even position on the tree. One researcher has shown that firmness is increased if apples are sprayed with a hormone while on the tree. Bourne himself has been most interested in how apples ripen and age in storage.

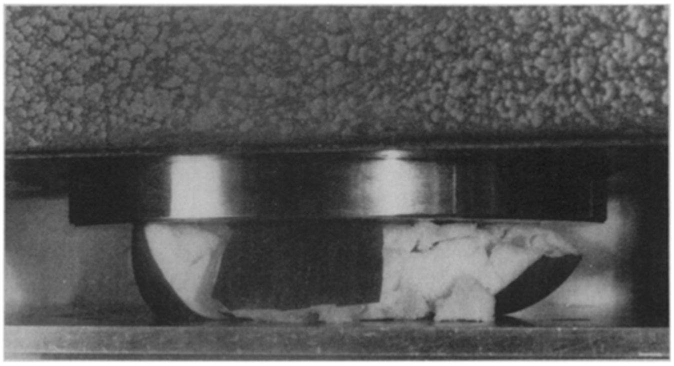
Apples, he says, like other fruits and vegetables, are living entities after they are picked; they actively metabolize organic compounds present in their tissues, generating heat and carbon dioxide and consuming oxygen as they respire. The fleshy edible parts of the apple consist

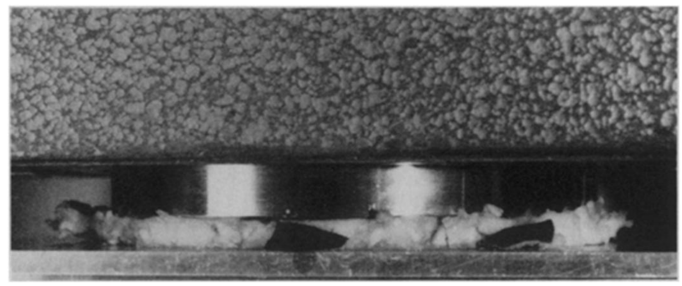


Bourne

Texture Profile Analysis of Delicious apples as a function of time spent in cold storage.

GET THE BRUISE





Bourne

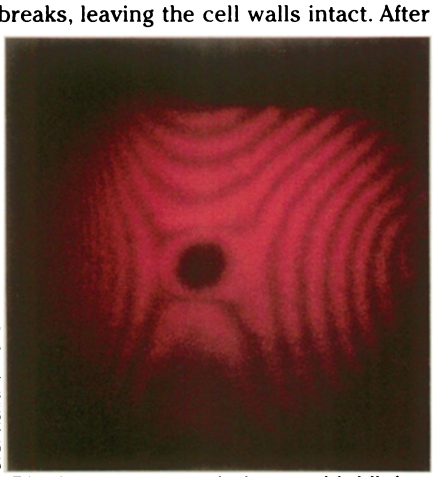
predominantly of parenchyma cells, which absorb water and puff out, generating a hydrostatic pressure called turgor pressure. This turgidity, which can reach as high as 200 pounds per square inch, is what causes rigidity and crispness in plants.

Surrounding the parenchyma cells, like mortar around bricks, explains Bourne, is an amorphous layer called the middle lamella. When an apple is fresh, the middle lamella is very strong — stronger than the walls of the parenchyma cells, which rupture when the apple is chewed. "When you bite a freshly harvested New York McIntosh, for example," he says, "the juice just seems to leap out in your mouth." In storage, however, biochemical changes weaken the middle lamella so that it breaks, leaving the cell walls intact. After six months, he says, the apple cells are like little sacs of water that do not break when chewed. The apple feels dry, even though the moisture content as determined by chemical analysis is the same as the juicy apple eaten in autumn.

Bourne uses mechanical instruments to evaluate the firmness and other textural properties of apples. He wishes that apples were as well behaved as peaches and pears, which exhibit an essentially linear decrease in firmness with time. But the apple, which deteriorates more slowly as it ripens, is the most difficult fruit to work with. "I've studied apples for a number of years and I still don't understand what's going on very well. I have notebooks full of numbers, but no consistent data."

Even with consistent numbers and supermachines that could dissect and analyze every component of the physical properties of apples, it would all be meaningless, says food scientist Martha Stone (favorites: Delicious, Jonathan) at Kansas State University in Manhattan, unless this objective data could be related to how the apple feels in the human's mouth. And that, say researchers, is no easy task.

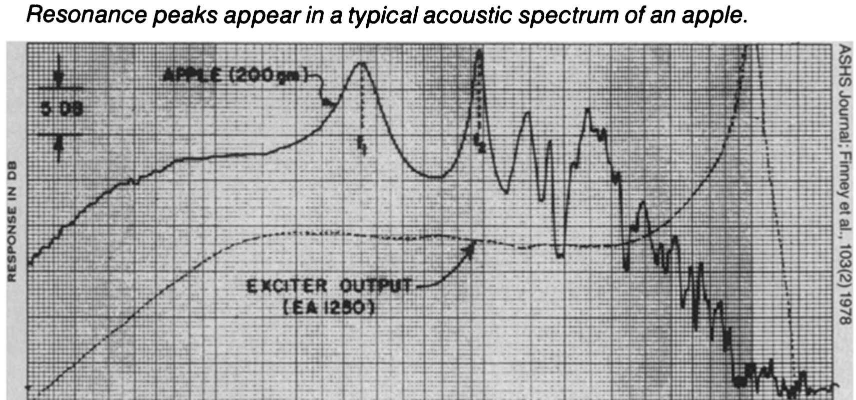
Part of the difficulty is semantics. To one person "crispness" may relate to the sound of the food while it is chewed, while to another it may denote the force required in the first bite. Volunteer panelists are usually chosen and trained to distinguish and rank different textural qualities. In a study by Donald D. Hamann (Yellow Delicious and Wine Sap) at North Carolina State University in Raleigh, for example, panelists were told to orient a piece of apple in a specific way in their mouth (to replicate how a machine would smash it) and rate properties like chewiness (num-



C.S. Vickram/M.G. Sharma

Black spot seen on hologram highlights damage to apple.

Resonance peaks appear in a typical acoustic spectrum of an apple.



ber of chews required to prepare the sample for swallowing) or firmness (the force required to bring the teeth together in the first bite). Hamann then tried to correlate the panelists' evaluation with the stress applied to the apple before it collapses.

Judith A. Abbott (Jonathan and Stayman) at the U.S. Department of Agriculture in Beltsville, Md., has performed similar studies relating mechanical properties to sensory data. She says, "Sensory responses are so individualistic. I don't think we're ever going to have an absolute accurate measurement of them, but I think we have a pretty good handle on it."

Bourne says that in general the more fundamental the mechanical testing, the harder it is to correlate sensory data with mechanical properties. Researchers have had the greatest success, he notes, relating subjective information to the Texture Profile Analysis (see sidebar).

According to Derl I. Derr (Cortland, McIntosh ... "all of them"), the executive vice-president of the International Apple Institute, a trade association in McLean, Va., in 1982 farmers received almost $900 million for their apples. One would think that suppliers of cultivars would be concerned about texture, but Bourne says that the grading and quality of most fruits and vegetables in the U.S. is heavily oriented towards appearance — shape and color — with less attention to flavor and texture.

Food companies that process foods, on the other hand, seem more aware of the importance of texture. Hamann notes that apple sauce is made from apples that retain much of their structure and cell walls when they are mashed, so that the sauce will be grainy. Acidity is also important, he says, and towards the end of the season, when acidity is low, companies will often ship in apples from other regions. Rome Beauty and Wine Sap are good processing apples because of their texture and acid levels; whereas Delicious are used in smaller amounts to make sauce.

One wonders how these food scientists face their own kitchens after a long day of squeezing and smashing food. That's not so hard, says Martha Stone. "But people have been a little wary about asking my husband and me to dinner because they are afraid I'm going to analyze the food." □

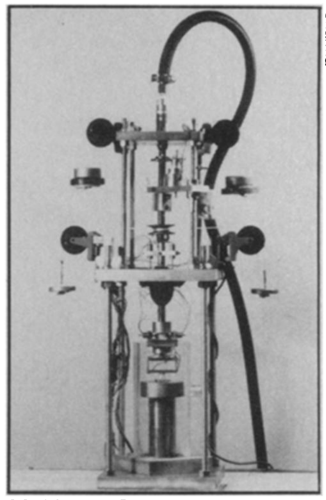
Texture technology: Acoustic apples and the motorized mouth

In laboratories around the world, apples and other foods from hot dogs to sticks of butter are being twisted and stretched, punctured and probed, crushed and compressed by devices with names like Pea Tenderometer, the Penetrometer and the Kramer Shear Press. Since the late 19th century, scientists have cooked up a veritable torture chamber of instruments aimed at extruding the textural secrets of foods and monitoring the quality of food commodities. The meatiest advances in food rheology have come in the last two decades with the incorporation of computers and techniques borrowed from materials engineering and physics.

According to Malcolm Bourne at Cornell University, the first objective technique for measuring apple texture was devised in 1917 by O. M. Morris, whom Bourne calls the "father of texture measurements." Morris's method was to partially embed a marble in paraffin wax and measure the force, as read off a kitchen scale, required to push the exposed portion of the marble into the apple. This was the first fruit puncture test, designed to mimic the jabbing motion of the thumb as one indication of firmness. Deformation, the distance a fruit compresses under the action of a force, is another measure of firmness. Over the years, scientists have developed shearing, puncturing and deforming instruments that perform what Bourne calls empirical tests.

Food technologists have also built mechanical mouths, machines designed to mimic the chewing action of the jaw. Bourne says that the first such device, the MIT Denture Tenderometer, consisted of a set of motorized dentures. Subsequent improved instruments enabled researchers to record the forces involved in the mastication of a food as a function of time. Scientists at General Foods have developed what they call a Texture Profile Analysis that allows them to extract textural properties such as hardness, fracturability, springiness, gumminess and chewiness from the force data.

A number of researchers working with foods have engineering backgrounds and, like M. G. Sharma at Penn State, "want to approach the problem from a more fundamental aspect." So they have devised methods of measuring basic physical quantities such as the elastic modulus and the sheer stress of foods in much the same way they would study the structural properties of steels or plastics. However, Mohan Roa, a food engineer at the University of Georgia in Athens, says, "Foods are very different from most engineering materials in terms of homogeneity and isotropy. Even with engineering materials we make lots of assumptions — it only gets worse with foods, especially those foods that are nature-made, like apples. With man-made foods you can control a lot of things; like when you make a hot dog, you can make sure it's homogeneous."



Sharma

Multiaxial Creep Apparatus.

An obvious drawback to all of these tests is that they destroy or damage what they are testing. So researchers have looked for nondestructive means of obtaining textural data. Judith A. Abbott and Essex Finney at the U.S. Department of Agriculture have measured the response of apples when they are suspended and mechanically vibrated at sonic frequencies. As the driving frequency is varied, the acoustic spectrum of the apple emerges. The researchers have correlated the resonance frequency of the apple with its firmness; softer apples tend to resonate at lower frequencies. They also found that apples that have been severely bruised exhibit a sharp drop in resonance frequency. Acoustic vibration, says Abbott, "is a good predictor of quality of groups of apples, but less so for individuals. It is also not as good a measurement of texture as the destructive methods."

Sharma notes that horticulturists have considered using ultrasound to test quality and ripeness of apples while they are still on the tree. However, Abbott says that there would be so many competing vibrations from other parts of the tree that she doesn't foresee it being a very practical method. "Intuitively, it sounds like it's going to be a lot of headaches."

Computers have been invaluable to food rheologists in dealing with a large number of variables at once. But even with computers, says John J. Powers of the University of Georgia, "We humans are so much greater than machines because we can sense things, analyze them. We interpret all the interactions among the different components in a food and we come up with a one-word answer all in a matter of milliseconds. When you drink a cup of coffee, for example, you're responding to at least 600 different chemicals. And there just isn't any machine that's going to be able to do that."

—*S. Weisburd*