an institute staff member), has shown that after latching onto a host's cells, virulent *E. histolytica* strains can destroy them by phagocytosis—simply gobbling them up. The key evidence comes from landmark 1983 work in which Orozco took bacteria that had a gene making them sensitive to light and fed them to a pathogenic strain of *E. histolytica*. She then illuminated her samples, a treatment that selectively killed bacteria-filled amoebas. The amoebas that survived were those that had engulfed fewer bacteria because of a decreased rate of phagocytosis. When tested in cell cultures, they turned out to be dramatically less virulent.

Isaura Meza, who heads the cell biology department at CINVESTAV, is studying the molecular mechanisms behind *E. histolytica's* cell-killing ability. Meza's specialty is the cytoskeleton of *E. histolytica* and, in particular, the role of actin, a protein that helps the amoeba move. As Meza, her co-workers, and others have shown, actin is a lead actor in the process by which *E. histolytica* binds to a host's cells and lyses them, a cell-killing mechanism that is separate from phagocytosis. Meza also helped identify a surface protein of *E. histolytica* found mainly in people who have symptomatic disease. If the amoeba does indeed have two strains, she says, this protein may be a key to distinguishing between people who are infected with pathogenic and nonpathogenic strains.

ADOLFO MARTÍNEZ-PALOMO

Tough customers. *Entamoeba histolytica*, the organism that causes amebiasis.

Besides these three CINVESTAV researchers and their co-workers, half a dozen other Mexican research groups at other institutions have shed much light on amebiasis. And all of these groups are continuing to train a new generation of amebiasis researchers. "This is one of the few fields in science where Mexico is a leader," Martínez-Palomo says, and if the efforts by him and his colleagues pay off, Mexican researchers are likely to remain at the top for years to come.

–Jon Cohen

MEXICO

Project Refines an Ancient Staple With Modern Science

SALTILLO, MEXICO—Build a better tortilla-making machine, and the world will beat a path to your door. At least that's what scientists in this sleepy town in northeastern Mexico hope. Two years ago, this group of physicists, biochemists, cereal chemists, and mechanical engineers launched the Tortilla Project to improve the making of the tortilla, an ancient Aztec delicacy that is a staple at tables throughout Mexico and Central America.

Why tinker with success? Much loved as the tortilla is, this corn pancake is also a water-guzzling, energy-sapping, polluting beast. But by applying the tools of modern science, from x-ray diffraction to stress analysis, the Tortilla Project scientists have developed a prototype machine, about 4 feet tall and five-and-a-half feet long, that could tame the tortilla. The contraption, which Rube Goldberg would have appreciated, "can go from corn to tortilla in 5 minutes," explains physicist Jesús González Hernández, who heads the Tortilla Project and is director of the Center for Research and Advanced Studies (CINVESTAV) branch in Saltillo. "In commercial plants, this takes 8 to 18 hours." González adds that the new tortilla machine is also energy-efficient, wastes no water, creates no pollutants, and produces a product that is more nutritious than the traditional tortilla.

The project has had top-level government support. Indeed, it was dreamed up by Feliciano Sánchez Sinencio, a physicist who until last month headed the entire CINVESTAV, a network of government-funded research and development centers with headquarters in Mexico City. And research officials point to the project as a prime example of applying the tools of modern science to tackle social problems that are important to Mexico and do high-quality research at the same time. Says Sánchez: "If you work on tortillas, you can do as good work as if you were working on fullerenes, superconductivity, or magnets."

Sánchez cites statistics to show why the government has been so keen on the Tortilla Project: Mexico consumes more than 10 million tons of tortillas each year. For each ton, 10,000 liters of water are used to soak and wash the corn. Not only is water a precious resource in much of Mexico, but the discarded water also contains high concentrations of lime—calcium hydroxide—which is one ingredient in tortilla making. "We're producing 800 million tortillas a day, and that means there are rivers of water with lime that are contaminating Mexican fields," says Sánchez.

The cooking process is just as wasteful. While more than 40% of Mexicans still make their own tortillas from scratch, many others buy their daily tortillas at tortillerías, small shops that are as common as convenience stores are in the United States. Tortillerías are equipped with gas-fired tortilla makers, which make and cook fresh tortillas from industrially prepared dough, called masa, or from corn flour. The energy inefficiency of these machines is evident in almost any tortillería, which are famous for being sweatboxes.

The challenge facing the Tortilla Project team—which includes physicists Elías López Cruz and José Martínez and cereal chemists Fernando Martínez Bustos and Juan Figueroa—was to understand how the traditional steps of tortilla making affect the product, then develop more efficient substitutes. The first step, traditionally, is to mix corn kernels with water and lime, then boil them for 45 minutes. Afterward, most people let the mixture soak overnight, although industrial makers cut soaking time down to as little as 4 hours. The lime-contaminated water is then dumped, and the corn is repeatedly washed, eliminating excess lime—along with nutritious parts of the corn kernel. This "nixtamalized" corn is ground into masa, which can be shaped into tortillas and cooked or dried and ground again into flour for later use.

Because the purpose of this process is to give the lime and water a chance to interact with corn starch and gelatinize it, the CINVESTAV workers reasoned, why not grind the corn to begin with? That should make it easier for the water and lime to mix with the starch, speeding the process and reducing waste. Using the known diffusion coefficients of water and lime in starch, they then calculated the optimal size for the corn particles at 150 microns.

Next, they calculated the precise amount of lime needed to make a tortilla that tastes as good as the traditional one and has similar physical properties. Using x-ray diffraction, they studied how different lime concentrations lead to different degrees of cross-linking between the corn sugar and the water molecules, a key factor determining the plasticity of the tortilla. They also examined how various lime concentrations affected tortilla firmness with a Universal

A Mexican-Bred Super Maize

If the Mexican scientists developing a better tortilla (see main text) ever want a more nutritious strain of corn to make it from, they won't have to look far. A grain that could make tortillas or any other corn food virtually the equal of milk in protein quality is waiting near Mexico City at the International Maize and Wheat Improvement Center (CIMMYT). In fact, it has been waiting there, all but ignored, for more than a decade. Although so-called Quality Protein Maize (QPM) achieves its nutritional gains without sacrificing yield, appearance, or flavor, it has attracted few takers among the world's agricultural organizations.

"We're wasting the opportunity to improve the value of a cereal grain that feeds a lot of people directly or indirectly," says Evangelina Villegas, a now-retired Mexican cereal chemist who developed QPM at CIMMYT during the 1970s and '80s with plant breeder Surinder Vasal. Villegas's frustration is shared by some of the world's top agricultural scientists and nutritionists. "In the Third World nations, there's every reason to get it out as soon as possible," says Norman Borlaug, a Nobel Prize–winning agronomist who headed the wheat program at CIMMYT for 35 years and now actively promotes QPM. But QPM has been dogged by the bad reputation of its predecessor, a high-protein maize known as opaque-2—and by nutritionists' uncertainty about whether there truly is a pressing need for more protein in the diets of the world's poor. As a result, QPM still needs to be adapted to specific regions to make it, for example, resistant to local pests.

Had QPM been developed in the early 1960s, it likely would have received a much warmer welcome. Back then, nutritionists considered the so-called "protein gap" between rich and poor to be an urgent problem. As a result, there was much excitement when Edwin Mertz, Oliver Nelson Jr., and Lynn Bates at Purdue University in West Lafayette, Indiana, developed opaque-2, which had substantially higher levels of two critical amino acids, lysine and tryptophan. But as opaque-2 was fieldtested, serious problems surfaced. The ears were small, yielding less corn, and the kernels were chalky and difficult to dry, making them vulnerable to fungi and insect attack during storage.

Villegas and Vasal picked up where the Purdue team had left off, painstakingly crossing opaque-2 with traditional maizes to introduce gene modifiers—genes that modify the way other critical genes are expressed. One by one, during 14 years of work, they bred in gene modifiers that corrected all of opaque-2's shortcomings while retaining its superior protein features. "It was an incredible achievement," says John Axtell, a plant geneticist at Purdue who works on increasing the protein quality of sorghum.

But just as QPM proved its worth in the early 1980s, the protein gap fell out of favor with many nutritionists. The general thinking, says American economist Donald Winkelmann, who stepped down as CIMMYT head at the end of 1994, was that the emphasis should be on calories, not protein. Adapting QPM to a specific region requires costly additional breeding steps, says Winkelmann, and "there are only a limited number of environments where people are willing to pay extra for lysine and tryptophan." At the time, CIMMYT was facing budget shortfalls, and after a nutritionist on CIMMYT's board was particularly negative about the supposed protein gap, Winkelmann decided to ax the QPM program.

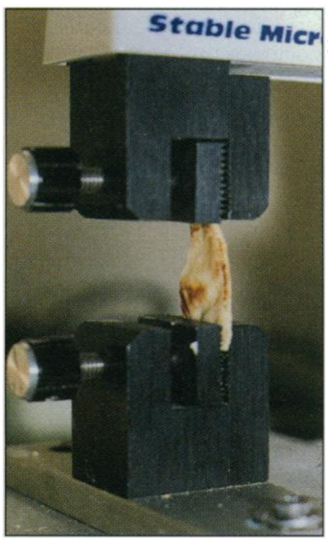
Studies during the past 5 years, however, have started to swing the protein debate in the other direction, says Nevin Scrimshaw, director of the food and nutrition program at the United Nations University and former head of food science at the Massachusetts Institute of Technology. "We have solid evidence that protein quality is a limiting factor for children and sometimes adults in rural, maize-eating populations where animal protein is limited," he says. Purdue's Axtell adds that although there was "an overemphasis on protein quality" in the '60s, "now it's gone too far the other way."

Villegas, who has been promoting QPM in Ghana, where infants suffer from protein deficiency, says what is needed now is a network of like-minded scientists to spread the gospel worldwide. Her vision came one step closer to reality in December 1994, when scientists gathered in Brazil for an international symposium where they discussed results from new studies with QPM and ways to increase its use. If her colleagues do step up their promotion, QPM may finally make its way out of the laboratory and onto the world's tables.

–J.C.

Texture Analyzer, a machine that stretches material until it breaks. The result was a recipe that uses exact amounts of lime and water—and thus requires no soaking and no washing—yet produces a tortilla that is both flexible and strong.

To determine precisely how long to cook tortillas of varying thicknesses made with varying lime concentrations, the researchers studied how heat passes through the material. They made these thermal diffusivity measurements by using photoacoustic spectrometry. This technique uses light to heat a tortilla sample stretched across the end of an air-tight cell. As the heat diffuses through the sample, it drives pressure changes within the cell, generating oscillations that are picked up by a microphone.



J. COHEN

Tortilla in traction. Measuring the strength of a tortilla, one step in developing a less wasteful recipe.

Rather than cook the tortillas with gas, they decided to use infrared light, which gives off less waste heat. To mete out the energy efficiently, they tuned the infrared radiation to a frequency that vibrates the hydroxyl molecule, a byproduct of the water used to make the masa. The vibrating hydroxyls then cook the tortilla.

The upshot of these studies in tortilla chemistry and physics is a prototype machine that makes a respectable-looking and -tasting tortilla without the usual downsides and is cheaper to operate than a gas-fired maker. The Tortilla Project team has filed four patents on the invention and is now negotiating with a corporate partner to build and market an industrial version of the machine. They estimate that their machine will cost roughly the same as the ones now used in tortillerías, which go for about $15,000 to $25,000.

Still, the scientists are not satisfied yet. "The flavor is there, but ours is still not as good in mechanical properties as the traditional tortilla," says González. Then again, he adds, "we are very close." So for now, the Tortilla Project researchers are going to keep refining their recipe for a 21st-century tortilla and tinkering with the machine that makes it until they have a product that the Aztecs would have enjoyed.

–Jon Cohen