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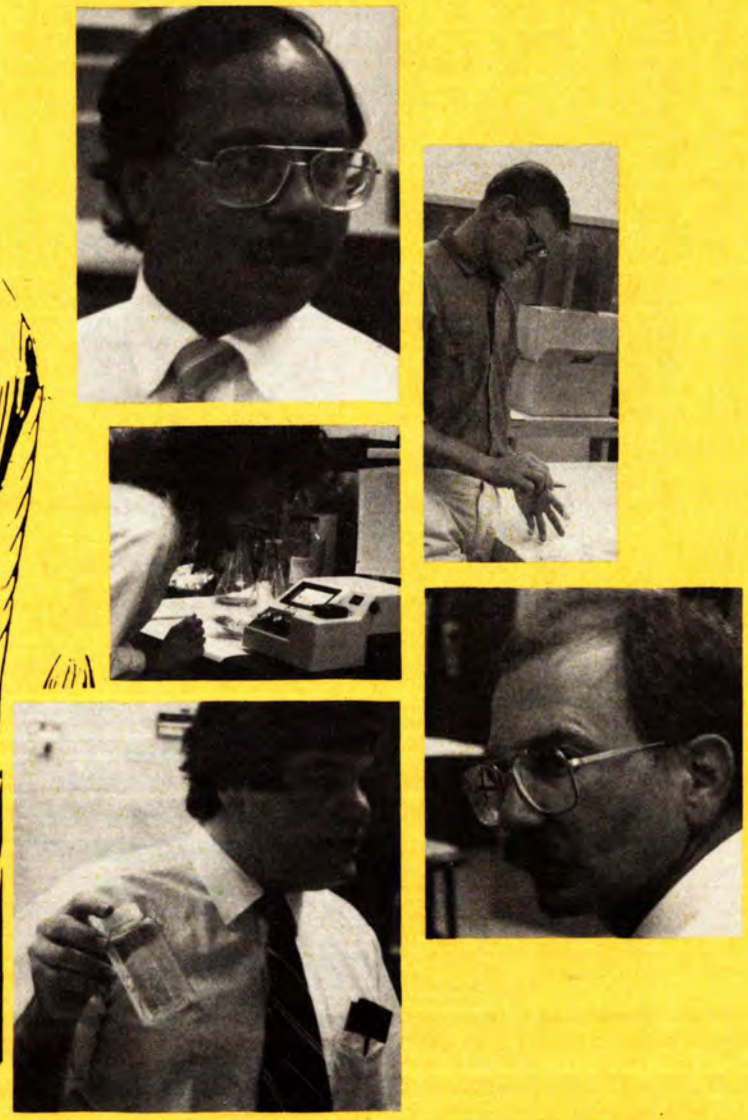

CORN RESEARCH

- cornstarch and plastic
- pullulan: medicine to oil wells
- feedlots: WPG
- winter roads
- foxtail in corn

Comments from the lab

The EC is flexing its muscles. Research and development will be how we stay ahead

Guest Editorial
Bill Gibbons

This issue of Farm and Home Research singles out research projects that the South Dakota Corn Utilization Council (CUC) supports with check-off funds from our state's corn producers.

The CUC has also financed some critically needed equipment and sent three faculty members and four graduate students to the National Corn Utilization Conference in St. Louis in June. Dr. Bill Gibbons represented the Agricultural Experiment Station and the CUC on a tour of European agricultural processing and utilization centers in August, a trip sponsored by the National Corn Growers Association (NCGA) and ICI Americas.

We have asked Dr. Gibbons to share some of his experiences with you. Bill has been involved in corn utilization work since he began graduate studies at this institution more than a decade ago.

Ray Moore, Director
Agricultural Experiment Station

It's been my good fortune to work with fellow SDSU scientists, private individuals, and organizations committed to developing an in-state industry for processing our raw agricultural commodities to value-added products.

One of the more active groups supporting ag processing development has been the state's corn growers. In this issue of Farm and Home Research we present the research projects funded by the CUC. They range from biodegradable plastics production to improved weed control methods.

This past spring, the CUC helped us in another way. We could purchase a state-of-the-art laboratory fermentor at a special discount, but only if we acted quickly. The CUC, working through the SDCGA, took advantage of this limited-time offer and purchased the fermentor for our use. This computer-controlled fermentor is the newest model on the market; it will enhance our research on production of acetic acid, pullulan, ethanol, and other corn-derived products.

Another farsighted CUC grant provided funding for Tom West, Padmanaban (Padu) Krishnan, four SDSU students, and me to attend the third Corn Utilization Conference held this past June. Scientists, industrial representatives, and producers from throughout the nation met to share corn utilization

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Corn check-off

New uses and new markets for corn are goals of CUC-funded research

South Dakota ranks ninth in the U.S. in corn production, yet corn prices in this state are consistently the nation's lowest.

This is because producers have no place to market corn in South Dakota. Sixty-two percent of the corn produced in this state is shipped out. The other 38% is fed back to livestock.

Dan Iseminger, administrator of the South Dakota Corn Utilization Council (CUC), says the Council was developed 2 years ago to help cure this worsening problem. Its purpose is to find new uses and markets for corn in South Dakota.

The South Dakota Corn Growers Association created the corn check-off. Through this program, corn producers give one penny per bushel of corn to the CUC. This money then is invested in programs where it will help research and marketing.

Iseminger says the South Dakota corn check-off is different than other check-off programs. Over 80% of the funds are invested in state and university programs rather than in national programs.

"We try to keep the money here because we feel South Dakota money should help South Dakota corn growers first, and help national corn growers second," Iseminger says.

Twenty-five percent of the money that stays in the state is granted to research and development through university programs. Dr. Bill Gibbons, microbiologist at SDSU, says the CUC met with an SDSU research committee back in March 1989. Several researchers had ideas involving corn they wanted to study further. The CUC narrowed the topics down to ones which would impact the corn industry the most, according to Gibbons.

The Council has granted SDSU about $268,000 to research in the past 2 years.

The grants make it possible for SDSU researchers to speed up their investigations into new and additional uses for corn, according to Dr. Ray Moore, director of the Agricultural

Experiment Station which oversees ag research at SDSU.

Iseminger says, "Once research is started we should see some solid results within 1 to 5 years, depending on the project. We have seen some immediate results already."

" We try to keep the money here because we feel South Dakota money should help South Dakota corn growers first . . . "

According to Don Johnson, chairman of the Corn Utilization Research Committee, some of the research is being done to prove a point.

"We want to be ahead of the game, and then propose the plan to farmers saying, 'this is working well, you should try it to see the results, too.'"

However, Johnson says, farming methods don't change overnight.

"It may be a long-time pull, that's why we need to keep the research going and keep working on our ideas," he said.

"The benefits from research done now will keep coming, not only to the corn producers of South Dakota, but also to the processing industry and other parts of the economy of the state, region, and country."

The projects at SDSU will take another year to complete. Once they are wrapped up Iseminger says he hopes the CUC and SDSU will continue to work on more projects.

"Dr. Ray Moore and this research team have some great programs," Iseminger says. "I think the growers feel good about what they have seen and about the check-off money going to these programs."

Moore says the research is benefiting both SDSU and the CUC. He says the goals and objectives of the CUC and the Experiment Station are the same, and that the grants enable SDSU to achieve these objectives more quickly.

Iseminger says the CUC is helping corn producers in ways other than research.

"Our state is doing things no other states have tried," he said.

South Dakota's is the only commodity check-off program in the nation that offers a low-interest market development loan program to businesses which will support the state's corn industry.

"We hope this will encourage businesses to come to South Dakota and use our corn. With this program everyone reaps the benefits," Iseminger says.

The CUC has granted money to several businesses which will utilize corn. One business which has benefited from CUC grants is an ice cream and yogurt company which uses all natural products. The products are made with corn sweetener.

Iseminger says the CUC has also contributed to building ethanol blending facilities in Aberdeen and Rapid City, as well as toward tripling the size of the ethanol production plant in Scotland.

" The benefits from research done now will keep coming . . . to the corn producers of South Dakota . . . to the processing industry and . . . the economy of the state, region, and country. "

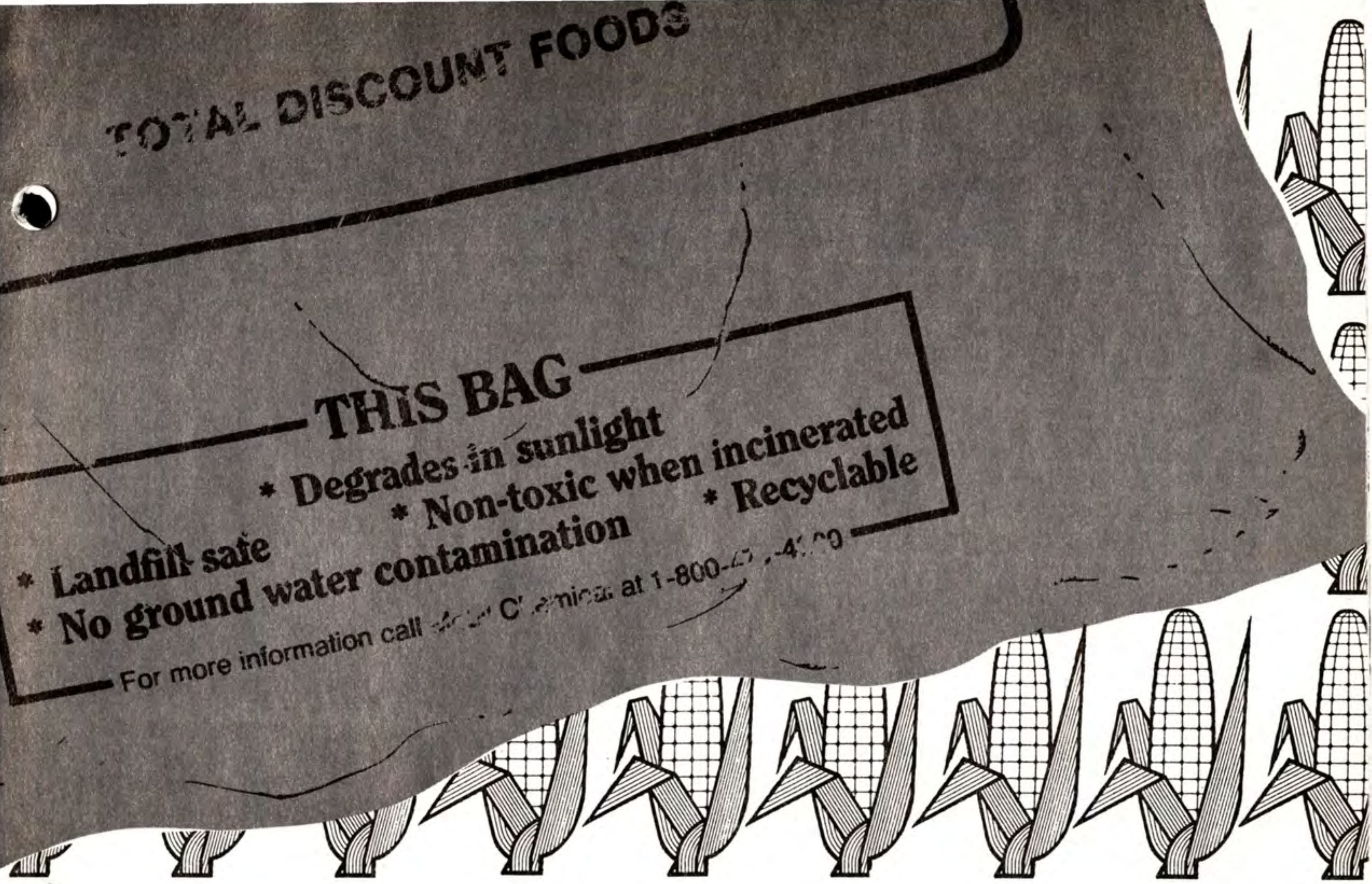
Corn producers are already seeing results from research done in the past few years. In the Scotland area, corn prices are $.12-.22/bu higher than in the rest of the state. Iseminger says this is due to the ethanol plant located there.

"Not only are the prices higher, but 75% of the corn used by the plant is damaged by heat or insects," he says. "So prices are higher for a lower quality product, because there is a use for it.

"The only answer out here to corn prices is to start building industries that utilize corn within the state," Inseminger says.

"But before we build we must have the research." ☐

The writer is Mary Kathryn (M.K.) McFarland, news writer in SDSU's Department of Agricultural Communications.



In plastic bags: cornstarch

Trio of SDSU scientists attacks degradability of plastic films

Once again, another eruption in the Mideast reveals our dependence on oil fields far from South Dakota. Once more come the calls for self reliance, for conservation, and for alternatives to oil.

One of those alternatives is being harvested from South Dakota fields again this fall; it is corn.

For every 10% of ethanol in gasoline, we burn 10% less petroleum-derived product. For every 6% of cornstarch in plastic films, we discard 6% less petroleum-derived product in our landfills.

It's high time to do something about our landfills. In 1970, 15% of the volume of municipal waste was plastic. That more than doubled by 1985 when 31% of the space in landfills held one-use-only oil-derived plastics.

Biodegradable plastics made with starch appear to be part of the answer to both dependence on oil and degradation of the environment. They provide another use for corn. When more of them come on the market, it will be because corn producers, industry, and researchers in South Dakota and the Midwest have cooperated in a mammoth effort to make plastic biodegradable.

Degradable plastics already exist, but there are still no industry standards. Yet in 1988 alone, 12 states in the U.S. banned or proposed bans on non-degradable plastic products.

The need to provide a scientific basis for such legislation, to lessen our dependence on petroleum products, and to find new uses for a renewable resource we have in bountiful yearly supply brought together three SDSU researchers who had little in common before this project.

One makes cornstarch-loaded plastics. Another tries to destroy them with a variety of starch- and plastic-eating microorganisms (MOs). The third measures how well the other two are doing. They are an agricultural engineer, a biochemist, and a food scientist. Their joint project is sponsored by the South Dakota Corn Utilization Council.

> ***" Biodegradable plastics made with starch appear to be part of the answer to both dependence on oil and degradation of the environment. "***

Jim Julson of the Agricultural Engineering Department is the maker of the plastics. He can cram as much as 50% cornstarch into an experimental polystyrene (molded plastic that cushions fragile goods during transit, for example), but his films (polyethylene) run from 0 to about 15% cornstarch.

He turns the films over to Dr. Tom West, Experiment Station biochemist, who feeds the strips to six different MOs with six different degrees of taste for the starch in the plastic.

Julson's assistant, Kent Klemme, an ag engineering senior from LeMars, Ia., retrieves the strips after the MOs have had their feed and measures the remaining strength in the plastic on a universal test machine that stretches and pulls the samples. Comparison with uneaten samples gives him a clue to the biodegradability of the plastics.

Meanwhile, Dr. Padmanaban Krishnan, assistant professor in the Nutrition and Food Science Department of the College of Home Economics, and his assistant Lucia Van de Crommert, food science senior from Slayton, Minn., are running chemical tests: Did the plastic really have the 6% cornstarch embedded in it in the first place? How much starch is left after the MOs finished their meals? Can Julson and West do their work all over again and get repeatable results?

When they pool their results, the three researchers will have standards and definitions for the degradable-film plastics industry. They will have used up a lot of cornstarch in the process, pointing the way to new and expanded corn markets for South Dakota producers.

And over the long run, perhaps their biodegradable plastics will play no small part in reducing our dependence on oil.

The engineer makes starch-loaded films

Jim Julson is the group's contact with the industry, and he's quick to give credit.

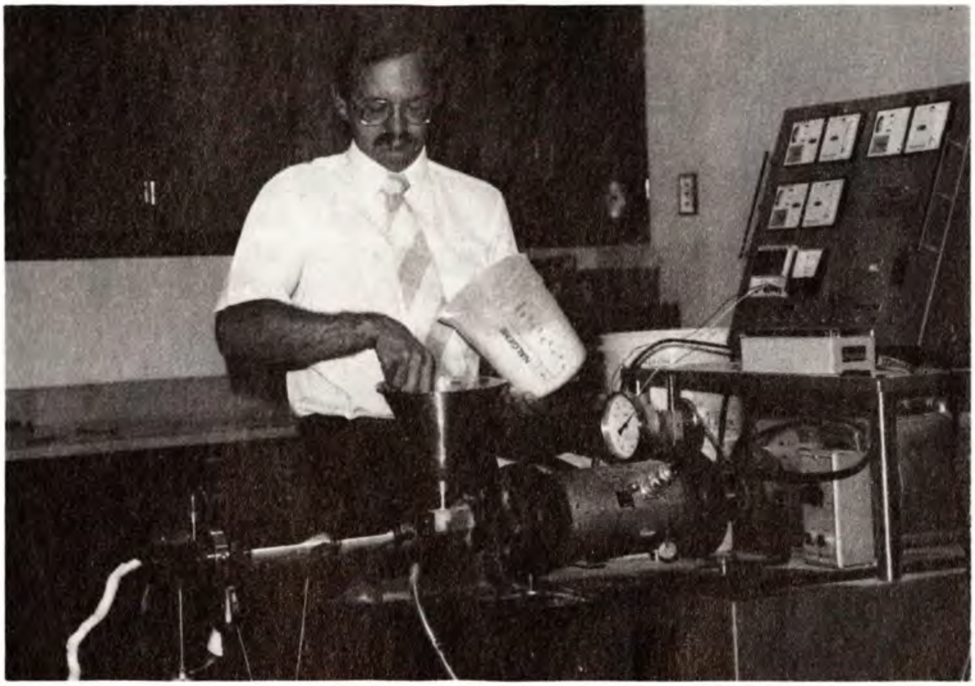
"Without Raven Industries and American Western Corporation in Sioux Falls we couldn't have gotten started," he says. "Raven supplies the film blowing extruder and AWC has the universal test equipment. They have a committed interest in degradable film plastic development."

Julson takes a commercial "master batch" of plastic/starch supplied by Archer Daniels Midland into Raven and blows it into film.

"Our polyethylene film starts as small beads mixed with starch granules," he says. "The extruder is a screw that pushes the beads through a heated barrel. The beads melt at the high temperatures and pressure created by the screw. The plastic is forced out through a die in the form of a cylindrical balloon."

The starch in the commercial master mix is cornstarch. Most commercial-grade starch-containing polyethylene is 6% starch. Also in the mix is an autooxidant, put there to enhance chemical degradation.

"Everybody talks about degradation or degradability, but nobody knows how to measure it in a plastic," says Julson. "Do you

Jim Julson is also loading polystyrene with corn. (Polystyrene is the "puffed" plastic often used to cushion objects during shipment; this lab-model extruder forms only "snakes.") What is coming out of the extruder is 50% corn; Julson and University of Nebraska engineers are now conducting tests to confirm its practicality for industry use. "That's 50% less nonrenewable oil resource and 50% more of a crop we grow every year," he says.

measure degradation by how fast plastic loses its strength or by the materials it forms during degradation?

"Some people would be happy if we just ended up with a lot of little pieces of plastic from one big one. But that stops short of ultimate degradation, which is biological conversion back to carbon and hydrogen or water and several other elemental products."

There are three different ways for plastic film to degrade. To understand their differences, you need a smattering of chemistry: Polyethylene plastic is made up of polymers, long chains of identical, individual units which turn out to be, in general, only tightly bonded carbon and hydrogen.

"Think of a log chain," says Julson. "That's like a polymer. Cut it to any length you need, it's still a log chain in one case and a polymer in the other. You haven't got carbon and hydrogen yet."

Photodegradation can be built into the plastic. An additive mixed among the links of the polymers is activated by ultraviolet light from the sun to break the polymers into smaller lengths. Chemical degradation is initiated by the interaction of an autooxidant and metal salts from the soil which ultimately also cause cleavage of the polymer chains.

Photodegradation and chemical degradation of plastic (your grocery bags probably say they are photodegradable) are only hacks with the bolt cutter; the result is still pieces of plastic.

" Grocery bags do not need to be starch free. In fact, . . . they could be 100% starch. "

Biodegradation is the ultimate breakdown. Each link in the polymer chain is changed to carbon and water. The "bio" in the word indicates that something living is responsible, and these living creatures are West's MOs and their naturally occuring relatives already living in the soil.

Three of the six bacteria that West is growing come from Peoria, Ill., and are "top secret" because they may be so starch-hungry and able to biodegrade plastic that they will be patented. (Peoria is home base for the USDA's Northern Regional Research Center which is primarily involved in ag product development; scientists from Peoria and the South Dakota Experiment Station collaborate on such projects.)

Most MOs can digest starch. So if a sprinkling of starch particles, also carbon and hydrogen bonded together in polymer lengths, is scattered among the polyethelene chains, the MOs recognize this familiar food. In digesting the starch, they increase the surface area available for chemical and microbial attack, and they release enzymes which also aid the break-up of the plastic polymers into their individual links, which then become an energy source for the MOs.

Julson has two goals for the research his group is conducting.

"We want some standards and the methodology for evaluating these standards. We have to all mean the same thing when we talk about biodegradability, or there'll just be inconsistent and unworkable legislation banning non-degradable plastics. The industry is very concerned that there are no standards or universally acceptable evaluation procedures."

Julson is also trying to load more starch--up to 15%--into the films. He's exploring other types of plastic material that may be compatible with cornstarch and still be acceptable for consumer use. More starch is more corn used, and that's good for corn producers, he says. But he will need to be selective.

"Plastic was originally conceived because it was stable and inert," he says. "The plastics industry spent a lot of time trying to prevent its degradation. For many applications it still needs to be inert and starch free."

Grocery bags do not need to be starch free. In fact, Julson suggests, they could be 100% starch.

"Starch is a natural polymer; polyethylene is a contrived polymer. Maybe we're just scratching the surface in the potential uses of starch and other natural polymers in the making of plastic materials. Maybe there's the potential to use the starch itself as the plastic."

In the meantime, Julson understands why the public is disenchanted with degradable plastics.

"The idea of biodegradable plastics caught fire so fast that the public got the idea that the plastic portion of the waste disposal problem was solved. But sometimes 'degradable' plastics don't break down or disappear as quickly as people were led to believe.

"Environmental factors themselves affect the speed with which the process occurs. The same material may begin to visually break down in a few days, for example, in the southern U.S. but take several weeks or months in the northern or western U.S.

"It's very important that we have good research to help us understand what's happening so we can regulate the degradation process."

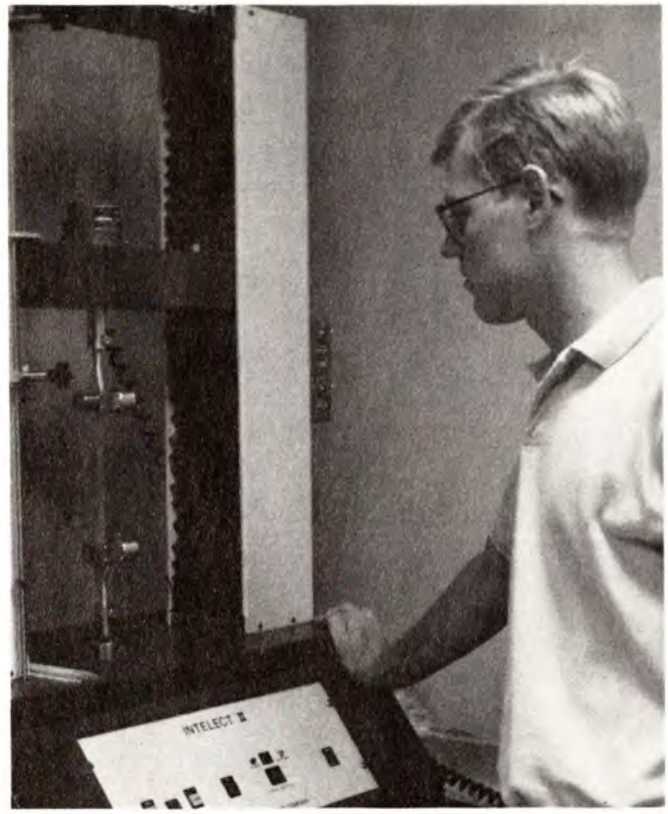
The biochemist feeds the films to his MOs

Tom West has invited six different types of bacteria to dine on plastic strips with six different levels of starch embedded in them. He offers nothing equivalent to dinner music or white tablecloths.

"I'm looking at basically the worst conditions possible under which those MOs might eat," he says.

"If they grow, it will be because they ate the cornstarch-plastic, not because they

MOs on the plates have no alternative. They either eat the starch and grow or decline the meal and die. The plastic strips, washed free of the bacteria, are taken to AWC's universal test machine by Klemme. Eventually, this strip, subjected to mounting strain, will "pop." When the scientists find the combination(s) of bacterium and starch content that initiate the biodegradability of plastic, their project will return benefits to producers, consumers, and the environment.



sneaked some nutrients out of the medium in which they and the plastic were suspended."

Besides supplying a nutrient-rich medium, researchers at other locations sometimes put the MO-plastic brew on a laboratory shaker.

" The industry is well along in incorporating starch into mulch films, seedling containers, and films for protecting roots during the transportation of plants and trees. "

"With all that jouncing around, sure, things are going to fall apart, but you won't know what caused the degradation. Maybe the shaking was responsible. Plastic, as it ages, becomes brittle sooner or later."

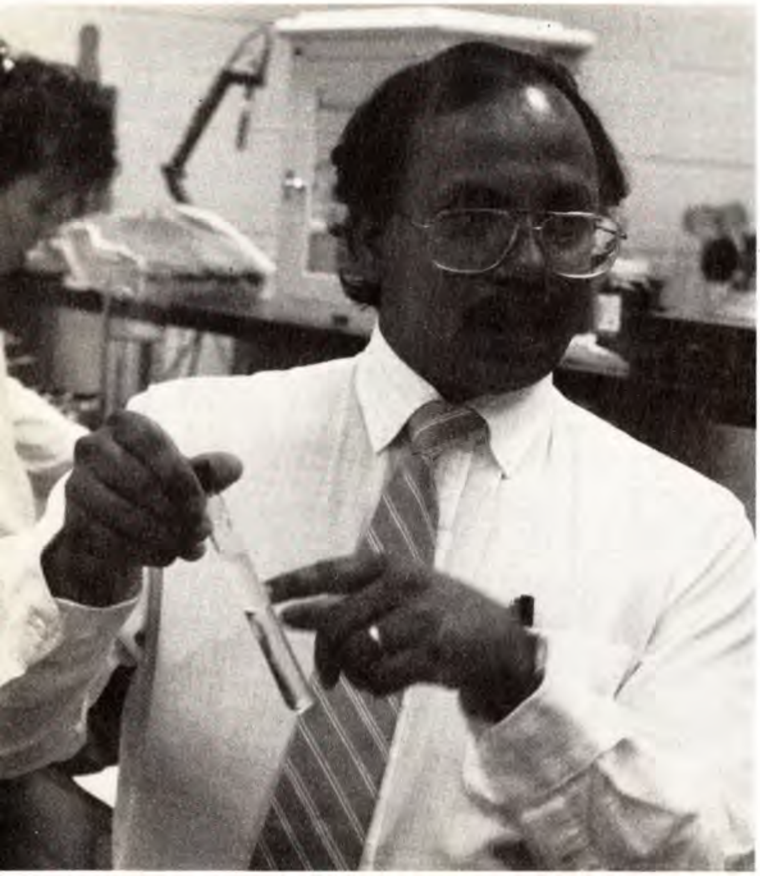
In nature, just because plastic breaks apart and disappears doesn't mean much, he says. The polymer chains, while invisible, may still exist. It may be years before the MOs have reduced them to ultimate carbon and hydrogen.

Other researchers have used "soil bins" stocked with a variety of MOs. "How do they ever sort out what happens," West wonders.

West sterilizes strips of Julson's plastic, drops them on sterile plates after dipping them in a pure culture of a bacterial species, covers the plate, and sticks it on the shelf. Some plates will sit there as long as 6 months. In another set of tests he has relented enough to add the bacterium in a saline solution.

The number of samples mounts up fast. With all bacteria, all starch concentrations, and all the environmental conditions that he will allow to be introduced, West is working with about 3,000 samples. "That's enough to handle at one time."

Kent Klemme comes by at regular intervals. He and West open up a set of plates and wash off and keep the bacteria. Klemme then takes the strips to AWC to measure changes in mass, tensile strength, and percent elongation.



Measuring starch itself "is no big deal," says Krishnan; foods scientists have been doing it for years. The trick is to get the starch out of the plastic, and that requires a new method which he has developed. He will discard the plastic/solvent mix at the top of the test tube and measure the color change in the bottom layer liquid in a spectrophotometer.

Part of that involves checking the thickness of the film strips, and it's no easy job. Starch granules are large and lumpy; they tend to bulge the plastic at the points where they occur and may even break the surface of the film. A complicated calculation taking the bumps into account complements the physical measurements.

And he applies the ultimate stress test, elongating the strips in the universal test machine and writing down the psi and amount of elongation at which the plastic goes "pop."

Can he tell any difference between the strips left over from the MOs' meal and the control strips?

"Not yet. It's too early; we're just into the project."

The researchers are meticulous. Even the direction in which the strips are cut from the polyethylene that Julson blew could make a difference. The polymers tend to line up on the sheet of plastic as it is formed. Cutting across the polymer chains appears to weaken the strength of the film.

It is too soon to tell whether any one of West's bacteria has a stronger appetite for plastic than the others. "We suspect that we have one really aggressive MO in the bunch," he says.

He's not saying which it is. Three strains are proprietary (under patent application). Some secrete enzymes that dissolve starch, others are partial to plastic. West thinks some can sniff out a starch granule buried under a cover of polyethelene.

West is well aware that conditions in his lab don't come anywhere near those of a landfill and that if he turned his MOs loose in a dump they might not eat plastic at all. "There may be something tastier. Or some other organism may eat our MOs first."

Being released in a landfill, however, would be like "going back home" for his MOs, West says. "Some of them are only generations removed from such a humble beginning. There are starch degraders out there right now that may be better than any of these bacteria."

Will a suspension of starch-eating bacteria ever be sprayed over a dumpground? West doesn't dismiss the possibility, but he says there will be a lot of research first to assure that the MOs are safe.

Landfills aren't the only destinations of starch-loaded plastics, he adds. "The industry is well along in incorporating starch into mulch films, seedling containers, and films for protecting roots during the transportation of plants and trees."

The food scientist measures what happened

Julson may use cornstarch in plastic manufacture and West may urge his MOs to eat the starch and dissolve the plastic, but neither scientist can tell with certainty how much starch they started with or ended up with.

Coming up with the numbers is Padmanaban Krishnan's job. In just 2 hours he can determine how much cornstarch is in a plastic film.

The cereal chemist says it's easy. "Basically, if you mix starch and certain chemical reagents, the solution changes color." The intensity of the color is directly proportional to the amount of starch.

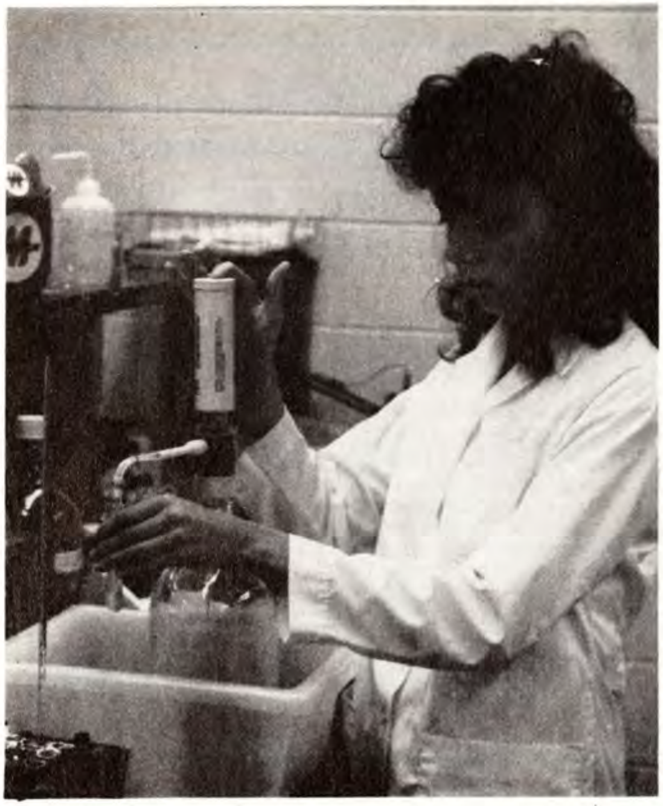
"Simple, accurate, repeatable," he says. "There are other complicated and 'wonderful' ways of measuring starch, but we can do it with chemicals bought right off the shelf and a standard spectrophotometer. The trick is to first free the starch from its plastic matrix."

That's been the sticking point for scientists and industry across the country. It's a quality-control issue which requires development of new methodology. Krishnan has developed a new method.

It is accurate because when a sample reads 6% starch on the spectrophotometer, a check of the records shows that 6%, not 5 or 7%, was added to that piece of plastic in Julson's extrusion. "Repeatable" means that "somebody else could step in and get the same results." No discoveries made by scientists are truly credited by their peers until this milestone is passed.

" What's ' biodegradable ' ? One company puts in 6% starch and calls its product biodegradable. Another company puts in 1% starch and calls it biodegradable. Without standards, how do we know who's ' right ' ? "

Krishnan skipped a few steps in his explanation, but chemists understand the verbal shorthand. For one thing, he's measuring sugar, not starch. Starch is just a long chain of sugar molecules.



While Van de Crommert works with solvents that have passed the dissolve-the-plastic criterion, Krishnan continues to look for one that will be even easier to use. He is also refining the process to account for colorants or other compounds that may be included in the plastic portion of the film. Industry standards for biodegradability of plastic are closer to reality.

The problem he had to solve: Could he recover all the starch from the sample to give the characteristic sugar reaction? Current recoveries seem promising.

Krishnan drops the strips in a glass tube and adds a solvent that dissolves the polyethylene plastic. Any starch in the plastic falls to the bottom of the tube.

Waiting down there is hydrochloric acid (HCl). "There's nothing new about HCl; it's a component of gastric juice." The HCl converts the starch to sugars.

Krishnan and Van de Crommert discard the contents at the top of the tube and add sulfuric acid ("right out of the bottle; it's simple") to the sugar solution. In its reaction with the sugar and the reagent, it produces a color change which the researchers can document in a spectrophotometer. It's a variant of a classic procedure.

"We could tell by looking, but the machine is much more precise. We put the tube in, the machine reads the level of absorbance, and by back calculation we can tell how much starch we started with. We're done."

"Starch is a natural polymer; polyethylene is a contrived polymer. Maybe we're just scratching the surface in the potential uses of starch and other natural polymers in the making of plastic materials. Maybe there's the potential to use the starch itself as the plastic."

Why is it necessary to know exactly how much starch is in a piece of "biodegradable" plastic?

"What's 'biodegradable'?" is Krishnan's response. "One company puts in 6% starch and calls its product biodegradable. Another company puts in 1% starch and calls it biodegradable. Without standards, how do we know who's 'right'?

"It's a matter of economics; companies can save by using less petrochemicals in plastics production, but what are the costs of 1% vs. 6% starch in a film? It's also a matter of compliance with any future specifications; will the company with 1% meet such standards for 'biodegradable products'? And it's an environmental matter; have we truly computed the costs of pure plastics and their impact on our enviromment?

"We scientists have to agree. We need a definition of 'biodegradable'. Is it time related? Does it happen within 100 years? 200 years? 2 years? Is it related to what form the plastic ends up as? Maybe if a piece of plastic breaks down into shreddable parts, it's biodisintegration. Maybe we save 'biodegradation' for the work of the MOs. Perhaps we should take the plastic to a point where nature can finish the job. Nature does this with other biodegradable things."

Krishnan is refining his method, trying different solvents, searching for the smallest sample of plastic he can use and still have a representative sample of the larger sheet, adjusting his readings from the spectrophotometer for any additives in the plastics.

"From this point, Jim (Julson) is going to make life a little more difficult for us in the lab. He's putting more twists in the plastic formulations--just to see if our procedure can handle sample diversity."

Krishnan is experimenting with an in-vitro (in the lab, in test tubes) model for monitoring degradation. By chemically labeling the starch with a dye before it is blown into the plastic film, he may be able to determine the extent of starch breakdown by following chemical, enzymic, or optical changes under controlled conditions.

Echoing West and Julson, Krishnan says landfills only hide trash away.

"By definition, a landfill is a place where you keep things away from nature--from moisture, light, living organisms that might degrade it. We've been talking 'landfill' all along, but what we really mean is big 'compost pile'.

"Nature intended compost and biodegradability. Everything in nature cycles down and up. Then we came along and designed plastic to be not biodegradable."

Composting isn't the entire answer, either. Recyling, burning, and other methods to handle trash may have to be employed, the scientists say. We need multifaceted approaches to handle a multifaceted problem. Starch from our corn fields is one of those answers. □

The Corn Utilization Council has funded the project of these three scientists at $40,000. Raven Industries and American Western Corporation, both of Sioux Falls, have permitted the use of their facilities and equipment.

PULLULAN

In oil wells, papers, clothing, medicine: Pullulan

Corn syrup provides diet for fungus with market potential

Dr. Tom West pours ethanol into a flask of clear liquid. White particles begin to form as he stirs.

He lifts the glass rod. It's coated with a white, gummy substance.

"Pullulan," says the Experiment Station biochemist. He pinches off some, and the substance strings from the rod to his hand.

To pronounce "pullulan," he advises, "forget what the word looks like. Say 'poo-yeh-len'."

You might need it someday when your oil well starts to go dry. Or when you need blood plasma.

to fund research that is truly basic and exploratory. Who knows when--or if--they will get any financial returns from the manufacture of pullulan?"

If they do, it will be because West has taken the guesswork out of the process. He picked *A. pullulans* for its superior production of the polysaccharide, grows the fungus in a weak corn syrup broth, and adds the alcohol to precipitate out and recover the pullulan.

It sounds simple because he has eliminated the pitfalls. "I tried cornstarch, corn meal, corn steep liquor, corn steep solids, corn gluten meal, a corn dextrin-maltose mixture, corn dextrin alone, even ground corn.

"Too bad the ground corn didn't work out. It would have been a direct route from elevator to pullulan. But the cornstarch in the grain kept getting in the way."

Somewhere "out there" may be a fungus that can eat ground corn and produce pullulan, West says. "Mine isn't the only pullulan maker, but it is easy to get along with. Some of the others I tried were stubborn; you couldn't count on them to perform."

Right now, corn syrup and corn dextrin-maltose produce luxuriant fungus growth, but neither match sucrose as a fungus food. The Japanese use sucrose. West, other researchers, and people in industry are watching the Japanese. Who are watching West.

Pullulan is gummy and highly biodegradable since it's mostly glucose. It coats Tom West's glass rod, and it stretches into a string when pulled. The Japanese are making it with sucrose as a food for the fungus. West is using a source closer to home: corn syrup from South Dakota growers.

Pullulan is made by a fungus with another tongue-twisting name, *Aureobasidium pullulans.* West feeds the fungus corn syrup.

Although he is probably the only scientist in the U.S. who's coaxing the fungus to accept corn syrup when it would rather dine on sucrose, West is not a lonely man. In fact, he's learned to keep demonstration bottles of his project on hand to show visiting scientists, politicians, and corn growers.

The corn growers have a vested interest in pullulan. It's their product the fungus is feeding on. It's their check-off money that's funding West's work.

"The Corn Utilization Council deserves a lot of credit for supporting this project," West says. "Not many groups would be so farsighted

" . . . corn growers have a vested interest in pullulan. It's their product the fungus is feeding on. "

"They've seen the market for pullulan. They're growing the fungus in big sucrose vats and taking out patents on the process. Up to now, we in the U.S. haven't worried about what pullulan can be used for. We haven't had it around to wonder what to do with it. Now scientists and the industry are talking about it."

The most likely use for pullulan is to put it down a low-producing oil well. Xanthan gum is already used this way, and pullulan is very similar. Because pullulan is extremely viscous, it would settle to the bottom, forcing deep oil up to within range of the oil pump. Pullulan may also be used to precipitate clay slimes in uranium or aluminum extractions.

Pullulan may also be part of the film coatings used in packaging foods and pharmaceuticals. Pullulan is mostly glucose; it stretches like a gum; and it is certainly more biodegradable than plastics.

"That will take some work," West says. "We will have to see how readily pullulan will go through an extruder and make a film.

"The idea of pullulan replacing totally plastic films appeals to a lot of us. There are lots of little microorganisms out in the dump who'd like to eat a glucose-based film."

Pullulan has a textile-like "feel." It would mix with papers and add water resistance to clothing. It may be an additive in foods and beverages, improving their texture, viscosity, dispersibility, and moisture retention.

"It's gunky in its pure state. It would make a good emulsifying agent. This is one application the Japanese are really working on."

" Pullulan is mostly glucose; it stretches like a gum; and it is certainly more biodegradable than plastics . . .The idea of pullulan replacing totally plastic films appeals to a lot of us. "

There is also hope that pullulan could be an inert carrier for vaccines.

"Pullulan causes no allergic reaction. It blocks the body from responding negatively to the vaccine." Pullulan is already being used in place of dextran as a blood plasma substitute.

Now that West has found the best corn substrates on which to grow pullulan, he will begin to add and withhold certain nutrients and vitamins to the fungus food. He'll be keeping an eye out for any mutants the fungus produces along the way. His ultimate goal is a faster and heavier producer of pullulan.

"I don't know if that will be easy or hard. I foresee a lot of test tubes and a lot of corn syrup and a lot of alcohol before we find out. We'll be looking for the strain that produces the biggest lump of pullulan."

" . . . pullulan could be an inert carrier for vaccines. Pullulan causes no allergic reaction (and) is already being used . . . as a blood plasma substitute. "

West tells other researchers about the progress of his fungus at national corn utilization council meetings. In turn, they tell him about their work. And the Japanese listen in.

"It's awesome how the Corn Utilization Council is supporting all angles of research that may lead to more products made from corn. They truly are looking out for the interests of South Dakotans and corn producers across the nation."

The Japanese delegates at the latest meeting tickled his funny bone.

"They brought an entire interpreter booth, and the scientists sat there with headphones on.

"That's okay. Sharing research results, having free access to information--that's the way we will make progress that will benefit all civilization. That sounds pretty high toned, but it's true. If pullulan plays a part in that progress, great!" ☐

Dr. Thomas West is associate professor in chemistry, working in the Agricultural Experiment Station's Oscar Olson Biochemistry Labs. His work on pullulan is supported by the Corn Utilization Council for 2 years at $39,900.

On winter roads: CMA

Salt's cheap only when spread. In contrast, CMA has no hidden costs

There's no connection between icy roads and corn crops. There may be no connection in the future, either, because the roads won't be icy. The corn will be the reason.

It's a long, slippery track from here to there. The roadmaps aren't even drawn yet. But a product made from corn may save us from the ditch, from rusted-out vehicles, and from crumbling bridges and roadways. It would be a welcome new use for corn and would reverse the degradation of our environment now caused by road salt.

CMA (calcium magnesium acetate) will be the corn derivative that makes this possible. Pelletized and mixed with sand, it could replace sodium chloride (common road salt) for road deicing.

CMA is less corrosive and less environmentally deleterious than road salt. In fact, the calcium and magnesium in CMA are plant nutrients, and the acetate is broken down and used by microorganisms.

Drs. Bill Gibbons and Carl Westby, SDSU Biology and Microbiology Department, are beginning the second year of studying the corn-CMA-clear road connection. Their names are already linked to ethanol production research at SDSU.

The on-campus ethanol pilot plant will likely give the two scientists a leg up on other researchers around the country, although Gibbons says otherwise.

"All of us are starting at the same point. I've talked to other researchers across the U.S., and we're all trying different routes to reach the same goal of making CMA for road deicing.

"It's true that our facilities here will be a boost, but we will have to make some modifications. Researchers from other states have said they want to work with us when they reach the point where they need to scale up their processes. We have the large-scale equipment that shows whether a project that works on the lab bench will work commercially.

"Until they are ready for that, we're plenty busy--we have our own project to design and conduct. We'll keep cooperating with them on lab sized development of alternative processes."

" . . . a product made from corn may save us from the ditch, from rusted-out vehicles, and from crumbling bridges and roadways. It . . .would reverse the degradation of our environment now caused by road salt. "

There are some rough stretches in the road from corn to CMA.

"CMA's more expensive than common road salt. Quite a bit. You can get road salt for $20 to $30 a ton. CMA costs $600 right now."

However, he adds, there are hidden costs in the salt price--costs of repairing roads, replacing fenders and rocker panels on vehicles, and cleaning up the environment.

"Those costs should be added to the price of salt to get the full picture," he says. "Then CMA may already be cost competitive with road salt."

The only company now commercially making CMA is Chevron, but production is limited to experimental batches produced from petroleum.

South Dakota seems a more logical place to make and use the CMA, says Gibbons. "We've got corn. We've got bad roads.

"This is another case where maybe we can keep the manufacturing at home instead of shipping raw products off somewhere else."

" CMA is less corrosive and less environmentally deleterious than road salt. In fact, the calcium and magnesium in CMA are plant nutrients, and the acetate is broken down and used by microorganisms. "

In rough terms, the steps Gibbons and Westby will use in CMA manufacture are (1) carbohydrates from corn to 2) ethanol to (3) acetic acid to (4) CMA.

The ethanol-to-acetic acid step is aerobic, meaning the scientists will add oxygen along with the calcium and magnesium.

They chose not to go anaerobic, a process some other scientists are working on. That method uses entirely different bacteria in a one-step conversion from corn glucose to acetic acid.

"Their anaerobic methods call for mixing the corn and the bacteria together, putting on the lid, and not peeking," Gibbons says. "But even if you don't lift the lid and let in air, oxygen usually manages to get in. Oxygen is a 'killer' to anerobic bacteria."

Theoretically, the anaerobic bacteria could produce more CMA from corn. But since these bacteria can't tolerate high concentrations of acetic acid or CMA, product recovery costs are higher.

In the aerobic process, glucose or other carbohydrates are first converted to ethanol by yeast or bacterial fermentation, and then the ethanol is oxidized to acetic acid by oxygen-using bacteria. The process produces higher concentrations of acid than does the anaerobic process and takes less time.

The first part of the process is familiar; it is an adaptation of the corn-ethanol fuel process.

Through the computer, Bill Gibbons sets the new fermentor beside it into action (left picture). Bill likes the automatic temperature, acidity, and nutrient adjustments, and he can draw off samples through a vacuum without shutting the system down. His favorite feature, however, is the adjustment for oxygen content, since aeration is the biggest consideration in making CMA. The liquid chromatography system (right), also purchased with CUC funds, prints out graphs in record time.

"But in making CMA, we don't have to be as precise in the ethanol step. We're not shooting for pure anyhydrous ethanol as we needed for the fuel additive.

"Instead, we just oxidize the ethanol in the fermentation broth to acetic acid. That eliminates any need for the costly and energy intensive distillation step normally required in fuel ethanol production."

To finish the job, "You add dolime, a calcium-magnesium combination, which causes the acetic acid to precipitate out as solid CMA."

The major problem is how to develop a process that will allow efficient and economical production of the acetic acid. Solving that depends on whether Gibbons and Westby picked the right strains of aerobic bacteria. They're confident they did.

"We have the opposite problem of the scientists using the anaerobic approach," Gibbons says. "Where their bacteria die if they introduce air, ours will die if they don't get enough oxygen.

"So part of our project involves designing a high-capacity aeration system. We'll couple that to a process that continuously removes the acetic acid as CMA."

The alternative would have been "batch processing" in which the fermentors and stirrers are completely shut down and the CMA removed at intervals. Batch processing uses more energy and is more expensive.

Gibbons and Westby have installed some new lab-sized analytical and fermentation equipment, purchased with their grant from the Corn Utilization Council. They are becoming intimately acquainted with their bacterium-of-choice, an Acetobacter. They are ready to start bench-top experiments.

"We'll move to pilot-plant experimentation after we get some solid laboratory data that show economical production is possible," Gibbons says.

Meanwhile, drive carefully this winter. □

Dr. Bill Gibbons is assistant professor and Dr. Carl Westby is professor in the Department of Biology and Microbiology. *Their grant from the Corn Utilization Council has been funded for the first 2 years of a 3-yr project at $37,000. With sponsorship from the National Corn Growers Association and I.C.I. Americas, Gibbons also visited corn utilization centers in Europe this summer.*

In feedlots: WDG

It's a good feed but its 'shelf life' needed work

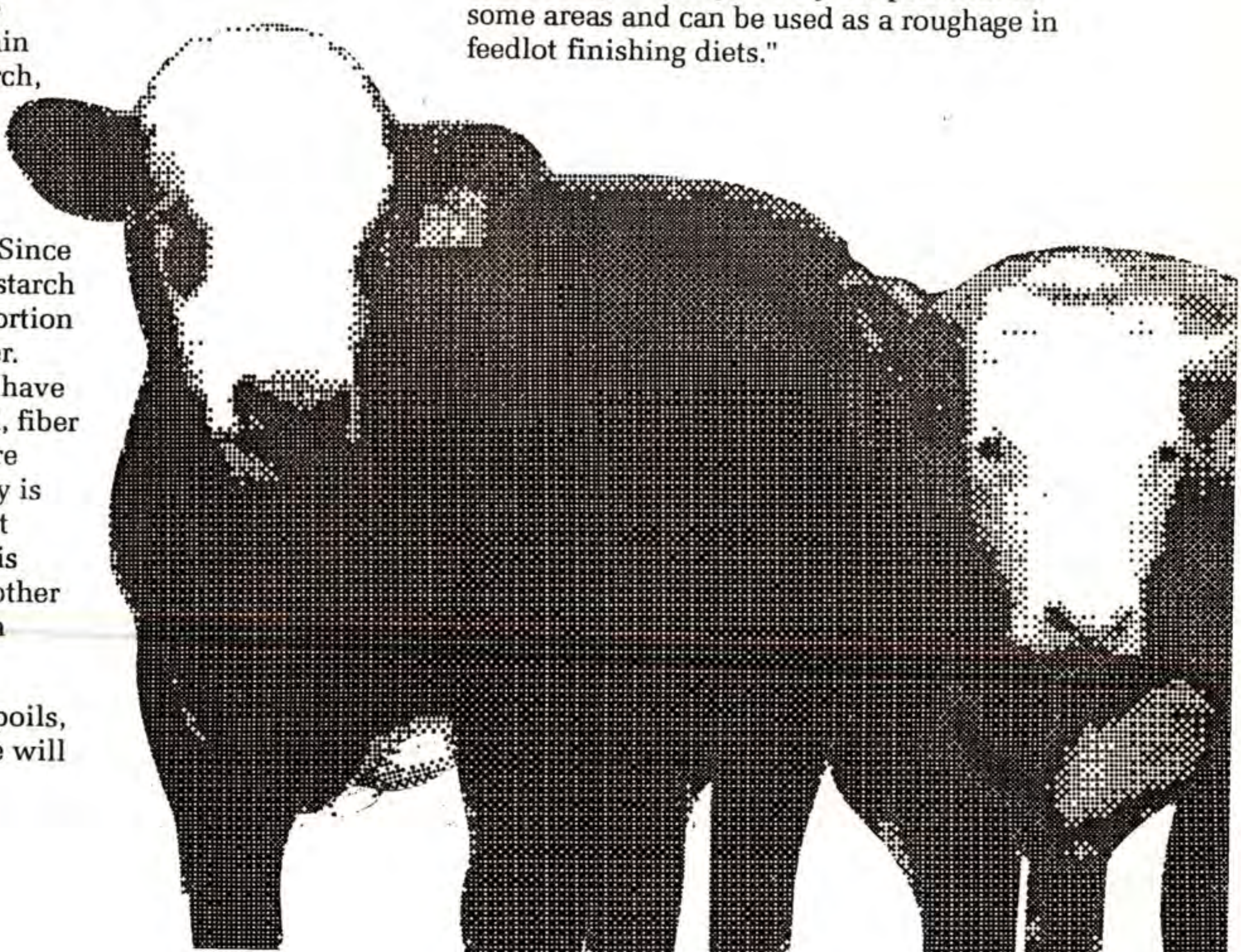
Cattle can make meat or milk out of almost anything. So some cattle feeders can turn to "alternative feeds" to use in a pinch, when the feed is available, or when the price is right. One of these alternative feeds is wet distillers grain (WDG).

Farmers in southeastern South Dakota have access to WDG; they can get this byproduct of ethanol fuel production from Broin Enterprises in Scotland.

"WDG is heavy and wet, about 35% dry matter and the rest water. Because it's so perishable, farmers must buy it treated with a preservative (which adds to its cost) or feed out fresh WDG in a matter of days," says Dr. Carl Birkelo, researcher in SDSU's Department of Animal and Range Sciences.

Even with these drawbacks, WDG is an excellent feed.

"For all practical purposes, it is the complete corn grain except for the starch, which has been removed by the ethanol producing microorganisms. Since the proportion of starch is lower, the proportion of protein is higher. Because they also have been concentrated, fiber and fat contents are fairly high. Energy is high. Therefore, at some price, WDG is competitive with other energy and protein feeds."



But if WDG spoils, Birkelo adds, there will be some loss of nutrients and feed intake will decrease.

Because of the high moisture content, cold weather can also be a problem. Freezing makes WDG difficult to handle and mix with other feeds.

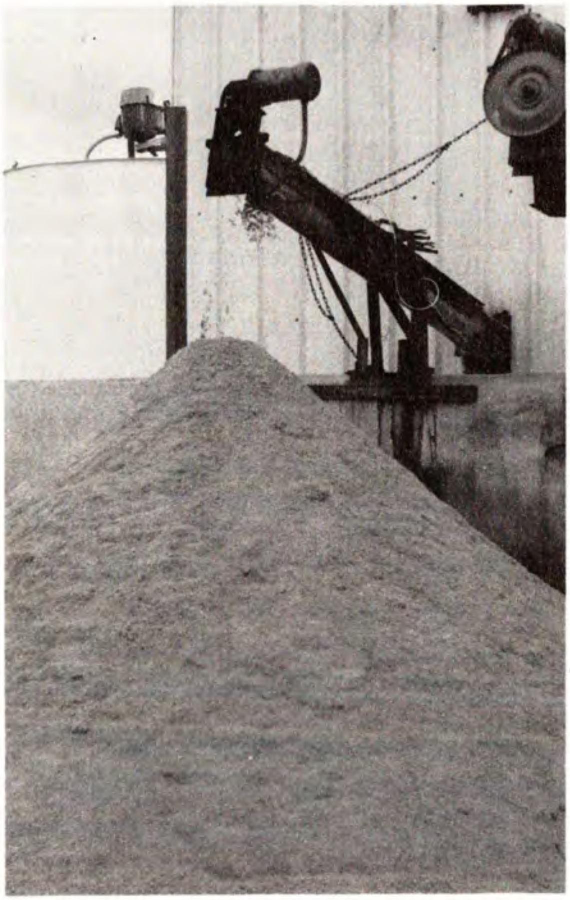
"We ran into that problem during the cold spell last December."

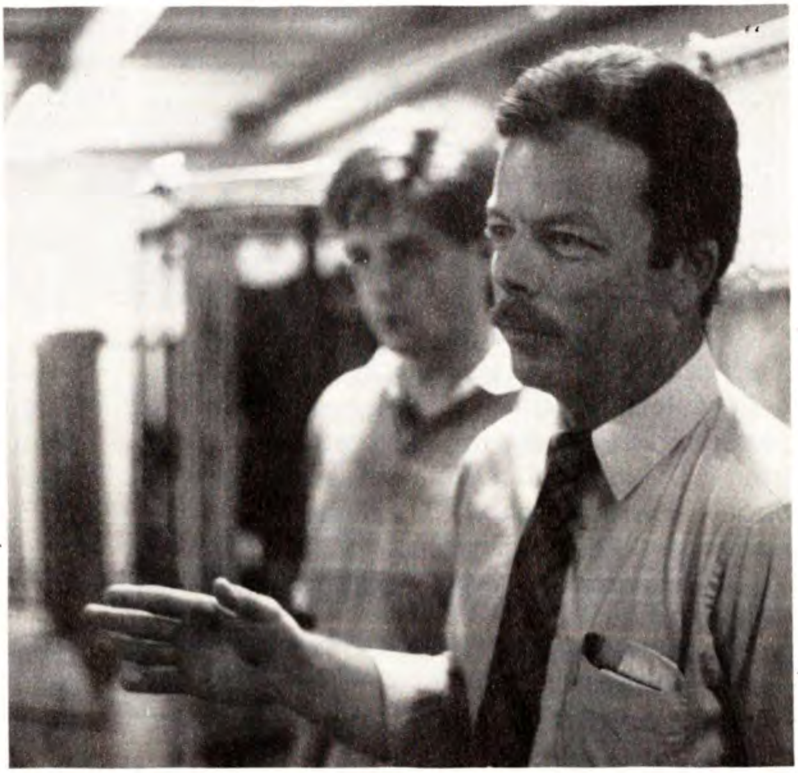
He'd expected it. Cold weather was actually part of his game plan.

"We felt we could increase farmers' opportunities to use WDG if we could improve its handling and storage characteristics. If these problems can be reduced, both cattle feeders and corn producers will benefit."

Two Corn Utilization Council grants helped fund Birkelo's research.

Oat hulls are a byproduct of the oat processing industry. "They are plentiful in some areas and can be used as a roughage in feedlot finishing diets."





You can find wet distillers grain (WDG) at the back door of an ethanol production plant, take it home, and feed it to your cattle. It's an excellent alternative feed component "when the price is right," says Carl Birkelo, "but it spoils quickly in warm weather or sets up solid in cold weather." Adding oat hulls and salt is the answer.

And oat hulls are about as dry as WDG is wet.

"We thought we might be able to combine oat hulls and WDG and see if the hulls would take up water from the WDG, consequently improving mixing characteristics when frozen and slowing spoilage of the feed when not.

"However, there's an upper limit on the amount of oat hulls that can be added. Hulls, while they are extremely high in fiber, aren't worth much nutritionally. We couldn't dry down the WDG enough by only adding oat hulls and still maintain the nutritional value of the diet. So we also tried different levels of salt to retard spoilage. Salt has been used in the past as a preservative in various situations, but not with WDG."

Most nutritionists use no more than 1/2% salt in feedlot cattle diets. But Birkelo says, "In practice, you can go higher than that and still be okay."

WDG represents only a part of the total diet, he explains. Consequently, the salt concentration used for preservation could be even higher.

"We decided on 5% as the maximum level. At that rate it is still a little cheaper than acid treatment of the WDG to avoid spoilage."

Animal research begins long before any critters come into the picture. Birkelo began in the lab, adding oat hulls up to 45% and white salt up to 5% of wet weight of the total mixture to samples of WDG. The combination went into glass jars that were stored without lids at 70 F. Other samples were frozen and then mixed with cracked corn.

"We watched for mold growth, and it wasn't long in coming."

Salt delayed the onset of visible mold up to 4 days. Oat hulls increased mold growth at low salt levels but decreased it at higher salt levels.

"A difference of 4 days doesn't help us much. Higher levels of salt or hulls might have delayed spoilage longer, but there was no point in finding out. In the feedlot, higher levels are not practical, either economically or nutritionally."

Oat hulls improved mixing characteristics of frozen WDG, particularly at 30% hulls or better. Salt was not expected to have any effect on frozen WDG mixing, and it didn't.

" We felt we could increase farmers' opportunities to use WDG if we could improve its handling and storage characteristics. If these problems can be reduced, both cattle feeders and corn producers will benefit. "

"Commercial acid treatment is the standard by which we measure protection from spoilage. Acid delayed visible mold growth 10 days at 70 F, while cool temperature (38 F) alone delayed it 13 days, compared to 2 days for untreated WDG at 70 F.

"Acid and cool temperature together delayed mold growth 100 days. Oat hulls, with and without acid and cool temperatures, still gave us more than 40 days of 'shelf-life' WDG. That's plenty of time in the winter to feed out a supply of WDG."

Birkelo picked the most promising combination from the lab work, a 30% oat-hull and 70% acid-treated WDG mix, to use in a cattle-feeding study at the Experiment Station's Southeast Farm near Beresford.

" (WDG) . . . is the complete corn grain except for the starch . . . Since the proportion of starch is lower, the proportion of protein is higher. Because they also have been concentrated, fiber and fat contents are fairly high. Energy is high. Therefore, at some price, WDG is competitive with other energy and protein feeds. "

Three treatment diets were divided among 81 yearling steers. On a dry-matter basis, the control group got 74% cracked corn, 17% oat hulls for roughage, 3% molasses, and 6% supplement. Another group got 30% plain WDG to replace 30% of the cracked corn. The third group got 30% WDG (mixed and stored with 17% oat hulls) to replace an equal amount of cracked corn and oat hulls.

"With this group we were checking feed intake and gain. If we couldn't detect spoilage, could the cattle? The reults are currently being analyzed."

If there is a benefit in feeding WDG and oat hulls, Birkelo says, "then we ought to look at them as roughage sources in feedlot diets. That is where our next study is headed."

WDG is a perfectly good feed. Cattle consume it readily and will have comparable dry-matter intake as those on corn.

Improving WDG's "shelf life" to keep it from spoiling or setting up in cold temperatures improves its competitiveness as an alternative feed. ❑

Dr. Carl Birkelo is assistant professor in the Department of Animal and Range Sciences. His Corn Utilization Council grant to conduct this project was funded at $34,500.

Not in corn fields: Foxtail

New breed of herbicides works on peskiest of weeds

Foxtail is the most common annual weed in corn, and South Dakota producers use preplant and pre-emergence herbicides to get rid of it.

The next major advance in foxtail control in corn will be postemergence herbicides, used after both the weed and the crop have broken ground.

There are good reasons to consider this move.

Herbicide only needs to be used if and where and when it's needed. In contrast, our current approach is to use a herbicide "before the fact," as a preventative under the assumption that it would have been needed eventually in the growing season.

Postemergence herbicides also represent the new breed of herbicides which have a short residual and which are used at extremely low quantities on a per-acre basis. This has implications for economics as well as the environment. It also reduces the risks of storing and handling large jugs or barrels of liquid chemicals vs. small boxes of dry material.

South Dakota farmers are doing a good job now of controlling foxtail. Postemergence herbicides will have to prove their worth before producers switch.

Data must be collected under conditions unique to our area. In many years, especially those with dry springs, the effect of early season competition is more critical than in other parts of the corn belt where moisture and growing season are not generally limiting factors.

For example, researchers in parts of the corn belt say that a postemergence treatment that removes foxtail any time during the first month is adequate. We in South Dakota know by experience this isn't good enough.

Studies started in 1989 at two locations, the Southeast Research Farm at Beresford and the Northeast Farm at Watertown. Both sites had relatively high foxtail pressure. Timing of removal was more important than the products themselves.

Corn with no foxtail control at all had dramatic yield losses--94% loss at Watertown and 39% at Beresford (Table 1).

Preplant incorporated herbicide worked best, providing over 90% foxtail control at both sites and giving the highest yield--92 bu/A at Watertown and 85 bu/A at Beresford.

Table 1. Foxtail removal systems in corn.

		Northeast Farm		Southeast Farm	
		%*	Bu/A	%*	Bu/A
	Check	0	5	0	52
PPI	Eradicane	94	92	92	85
PRE	Dual	32	4	55	67
EPOS	Accent	73	82	70	89
POST	Accent	92	74	72	82
LPOS	Accent	61	18	88	69
	LSD (.05)	18	23	15	16

* % foxtail control
Systems:
PPI = preplant incorporated
PRE = pre-emergence
EPOS = early postemergence
POST = postemergence
LPOS = late postemergence

The pre-emergence herbicide provided less than satisfactory control, and corn yields dropped substantially at both locations. This is directly attributed to the lack of rainfall the first 3 weeks following planting.

This yield drop underscores the importance of rainfall in herbicide performance. You should have auxiliary cultivation--harrows or rotary hoes--ready to go in years when rainfall is light.

You will find there is much more gain from removing the weeds as opposed to the loss of soil moisture by cultivation.

The experimental postemergence herbicide, applied early (10-14 days after planting) when the first foxtail flush was just emerging, provided 70 to 80% control and produced corn yields statistically equal to the preplant incorporated treatment.

Later postemergence treatments provided up to 88% control. However, yields were reduced 20% or more, when compared to the best treatments.

" Postemergence herbicides . . . have a short residual and are used at extremely low quantities on a per-acre basis. This has implications for economics as well as the environment. It also reduces the risks of storing and handling . . ."

This shows the importance of removing most of the weed competition during the first 2 weeks of growth. It also suggests that grass control may be less than 90% but crop yield will not be sacrificed if that competition is removed early. Some weeds will sprout after the treatment since the chemical has no residual, but they really don't hurt yields.

It is more important to get most of the weeds out early than to get all of the weeds out late.

"Weed tours" at various locations across South Dakota give Leon Wrage a forum of nearly 20% of the state's crop producers. He now has research backup when he shows how to control foxtail in corn by postemergence treatment. A "post-" is used only if, when, and where it is needed. It is also relatively "soft" on the environment, compared to other treatments.

When you see obvious weed pressure, consider postemergence removal as soon as possible. That's better than choosing an herbicide or cultivation program from the standpoint of "How long can I wait."

"Absolutely clean" is less important than early removal of most of the common weeds.

Postemergence treatments fit into an experienced producer's program very well. They are economic in that they are applied only when and where and if they are needed. They are environmentally more sound than other programs for the same reasons. They appear to fit South Dakota conditions.

So you check the fields, see foxtail sprouting, and it's early in the season. How much foxtail is too much foxtail?

This where you call on your own experience. Weed thresholds vary by location and year. When moisture and nutrients are short, the threshold is low.

" Postemergence treatments . . . are applied only when and where and if they are needed. They are environmentally more sound than other programs . . ."

We can't say that if you have 21 weeds, then you better spend the money to treat, but

Table 2. Corn herbicide rates.

Rates/Cultivation

		Herb	0 cult		1 cult	
		Rate	%*	Bu/A	%*	Bu/A
PPI	Eradicane/Bladex	Half	93	124	98	130
		3/4	98	126	99	133
		Full	99	132	99	132
PRE	Lasso/Bladex	Half	75	94	89	130
		3/4	83	113	93	135
		Full	84	118	97	136

Rate/Ridge-Till

	Herb Rate	%*	Bu/A
3 cultivations	---	80	99
Lasso/Bladex	Half	95	104
	3/4	97	108
	Full	97	96
LSD (.05)		12	NS

* % foxtail control
PPI = preplant incorporated
PRE = preemergence

19 plants are okay. Many of these grassy weeds stool and tiller. If the season turns off dry, half an "acceptable" number of weeds could produce a big yield loss.

Producers who understand their fields will have an idea of the weed threshold when they look early in the season. It's a judgment call, but make it early.

If the foxtail flush doesn't look too bad early in the season, and you get by with half of your usual chemical rate, are there any risks in doing that next year, too?

Another study (of both herbicides and cultivation in a corn-soybean rotation) answers this question. The treatments were both preplant incorporated and pre-emergence herbicides on each crop, applied at half, three quarters, and full rates. Each treatment had cultivated and uncultivated comparisons, each in a conventional-till and ridge-till system. The field had a relatively clean weed history.

The preplant herbicide in both corn and soybeans provided both excellent weed control and the highest crop yields of any treatment with or without cultivation at any of the rates (Table 2).

The meaning of that is clear: A full rate was too much for conditions in 1989.

By contrast, the pre-emergence herbicide provided 70 to 80% control. One early cultivation increased corn yield by 20 bu/A and soybeans by 15 bu/A. That's significant.

The one cultivation returned tremendous dividends. The one time we went out there (early), recognizing that weed control wasn't good enough, we got an additional 20 bu/A.

It's important to see that the pre-emergence treatments provided only about 80% control. Weed control is not a matter of one year at a time. We anticipate that reduced herbicide input without cultivation would be literally disastrous if continued in a 3- to 4-year rotation.

> *" Producers . . . will have an idea of the weed threshold . . . early in the season. It's a judgment call, but make it early."*

In the conventional system, one cultivation provided corn yields equal to the preplant treatments with the reduced or the full rate of herbicide.

The ridge-till results are significant. Ridge-till producers have felt for a long time that ridging effectively controls weeds. Our data after 2 years support this: Cultivation and ridging provided weed control and yields equal to banded full or reduced rates.

We now have a good start toward facts that are unbiased and localized for South Dakota. I have confidence in using them. Postemergence herbicides on corn for foxtail do work.

The key is still how early you use them. □

Leon Wrage, Cooperative Extension Service weeds specialist, is the author. *The Corn Utilization Council has funded a $11,800 grant to the W.E.E.D. project run by Wrage and Paul Johnson, IPM coordinator, to conduct this research.*

Comments from the lab

continued from page 2.

research and commercialization developments. We found that our own CUC-sponsored projects are at the forefront of research for the development of pullulan, biodegradable plastics, and calcium magnesium acetate.

We strengthened our ties with other scientists and companies working on similar projects. We gave and got "tips" and talked out mutual problems. Equally important was the exposure our students received. They saw the "scientific community" working together, and they saw how research moves from the laboratory to the pilot plant and eventually to the commercial scale.

This summer, I was honored to be nominated by the SDCGA and the CUC, and selected by the NCGA, to take part in a Eurotech Corn Tour and Conference. Twelve corn production and utilization scientists from throughout the nation, accompanied by NCGA and ICI Americas representatives, spent 12 days in Belgium, France, and the United Kingdom visiting with European Economic Community (EEC) representatives, commodity groups, industrial processors, and research scientists.

Highlights of the tour included 1) discussions with EEC commissioners who described agricultural utilization research and commercialization programs which have budgets of $150-200 million over the next 4 years, 2) presentations by scientists who developed a completely biodegradable plastic substitute made entirely from corn, 3) a tour of the first commercial-scale membrane unit for dehydrating ethanol, and 4) visits with producers firsthand. We also created linkages with our foreign counterparts to facilitate collaborative research projects in key areas.

One thing stood out very clearly:

U.S. agriculture is being challenged by a formidable competitor. The EEC has forged a strong coalition of producers, processors, and governmental agencies. It has committed hundreds of millions of dollars to agricultural production and utilization research.

For the U.S. to maintain its dominance in agriculture, we need to devote more resources to agricultural research and development, particularly in utilization and value-added processing.

Commodity organizations will play a key role in helping to shape U.S. ag policy that directs additional federal funding to utilization research. We are already seeing the results of this effort in the 1990 Farm Bill, which has placed much greater emphasis on agricultural research.

The outstanding support to university research that has been demonstrated by the CUC continues to provide a clear signal to the federal government that commodity organizations are willing to contribute their fair share toward research and commercialization funding. We at SDSU are pleased to work with this type of forward thinking organization, to benefit not only agriculture, but South Dakota's economy as a whole. □

Dr. Bill Gibbons is assistant professor in the Department of Biology and Microbiology.

Cover photos:

SDSU scientists from widely differing research specialties have come together to work on a Corn Utilization Council sponsored project on biodegradability of plastic films. Clockwise (beginning at lower right), they are Jim Julson of Agricultural Engineering and project leader, who makes the films with various amounts of starch granules embedded in them; Dr. Tom West, Station Biochemistry, who handles the bacteria that feed on the starch and break down the plastic; Lucia Van de Crommert, food science senior and assistant to Padmanaban Krishnan (top), cereals chemist in the College of Home Economics, who together pinpoint the exact starch content of the plastics and are preparing standards that will be used by the degradable plastics industry; and Kent Klemme, senior ag engineering student who measures the physical decay of the plastic.

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