Recycling Poultry Feathers

More Bang for the Cluck

What happens when an industry's by-product turns out to be as valuable as its primary products? The poultry industry may be about to find out. Scientists are exploring new methods for turning the industry's excess fluff into products ranging from notepaper to auto body parts to high-quality animal feed, saving trees and replacing man-made materials in the process.

The National Chicken Council, a Washington, DC–based poultry trade group, predicts that more than 8.5 billion chickens will be commercially grown and processed in the United States this year. These chickens, when processed, will leave behind more than 2.3 billion pounds of feathers. For the competitive poultry industry, the challenge is to turn the white plumes into valuable new products that add to the company's bottom line. Though there has been significant controversy in recent years over the human health effects of poultry wastes, especially used litter and processing plant wastewater that ends up in waterways, chicken feathers are relatively clean and do not generally pose a health risk. Contamination of feathers with chicken blood and feces can present a problem, but in general feathers are continuously removed from the processing area to make room for new feathers as more chickens are processed. An average chicken processing plant churns out 4,000 pounds of feathers an hour and has a low profit margin per bird, so feathers must be moved or processed quickly and very inexpensively.

The Keratin Connection

Feathers are made of keratin, the same tough, tightly wound protein fiber that makes up hair, wool, fingernails, and hooves. Walter Schmidt, a research chemist at the Beltsville, Maryland, branch of the U.S. Department of Agriculture's Agricultural Research Service (ARS), has found a new way to process poultry feathers into valuable fibers that can be made into other products. Schmidt, whose background is in physical and analytical chemistry, began working with feather keratin because he was studying another fibrous protein, collagen, and wanted to compare the physical properties of the two. But he noticed that the feather protein had properties in common with another fibrous material, as well: cellu-

lose, the starch that forms wood and paper. "Feathers are keratin just like wool," Schmidt says, "but the surface area is much larger because the diameter of the fibers is much smaller. So the fiber can absorb more than wool or cellulose fibers." The crystal structure of feather fibers also makes them naturally stable and durable. Thanks to these properties, feathers can be put to good use in the manufacture of consumer goods, replacing wood pulp and other expensive fibers.

The properties that make feather fibers valuable are intrinsic to keratin. "The real scientific innovation is that before we did this research, no one seriously thought of feathers as fiber, let alone as a viable and valuble source of fiber," says Schmidt. "Feathers are a great source of fine-diameter, high-surface-area, tough, durable fiber," he says, properties that make fibers, in general, valuable to many different types of manufacturers. Based on early production figures and the cost of similar fibers, he estimates that feather fiber will yield a profit of about 50 cents per pound, much more than the pennies-per-pound profit producers earn on chicken meat. A chicken has about five ounces of feathers and matures to harvest in 6–8 weeks.

Feathers can't be taken from the chicken and made directly into new materials, however. The stiff central core of the feather (the quill) must be stripped of the flexible, interconnected strands of material that emerge from it (the barbs). It is only this soft barb material that is useful as feather fiber. Although the whole feather is made of keratin, the crystal structure of the protein in the brittle central quill is different from that in the soft but durable barbs; only the barbs have the desirable properties.

Schmidt and his team at the ARS developed an efficient method for sorting quill from barb in chopped feather. Chopped quill and barb parts have a similar weight and density but very different shapes: chopped quills are more globular than the flatter chopped barbs. Turbulent air flow in a separating machine moves quill parts to the bottom of the device for removal while barb parts are blown to the top and collected for further use.

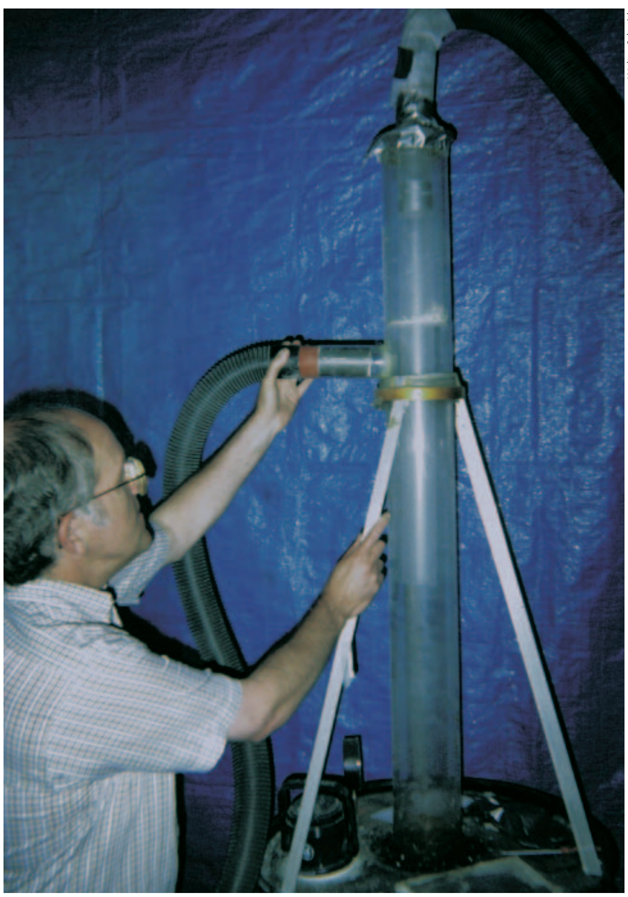
"The real technical innovation in this research," says Schmidt, "is that the fiber and the quill are efficiently separated from each other, and the fiber fraction is collected free of the quill fraction. Simply grinding up whole feathers leads to a product unacceptable to nearly all commercial fiber end users."

Fibers and Feed

The U.S. Environmental Protection Agency estimates that more than 16 billion diapers, made from wood pulp, are discarded each year. Schmidt estimates that a year's worth of feathers could replace approximately 25% of the wood pulp used annually for diapers. The environmental impact would go beyond saving trees: feathers require much less processing than wood pulp, and unlike paper pulp do not require bleaching—they start out white. Three companies—Featherfiber Corporation, Maxim Systems, and Tyson Foods—are now working to scale up production of absorbent feather-based products including diapers, filters, insulation, upholstery padding, paper, and clothing.

Individual feather fibers are too short to allow feathers to be spun into thread and woven into cloth, but they can be mixed with man-made materials like polyester and spun into thread, or they can be compacted into breathable nonwoven cloths like those used for hospital gowns. Other manufacturing treatments can yield products with far different properties: researchers have been able to make clear film from feather fiber by breaking and reforming the bonds between fiber strands.

The fibers have also been used in manufacturing plastics, mixing the feather product with man-made polymers to make hard, tough materials. The orderly structure of keratin helps stabilize the structure of plastics, making them stronger. "You can choose your binder materials to give a defined half-life," says Schmidt. "Polystyrene is going to be around for a long, long time because it's not a natural product. But you can choose to make plastics with binders that will break down."


Walter Schmidt

Flying feathers. Walter Schmidt shows off a prototype feather separator in which the flatter, valuable chopped barbs are blown to the top of the column, where they are collected for conversion into other materials. The more globular chopped quills fall to the bottom and are removed and discarded.

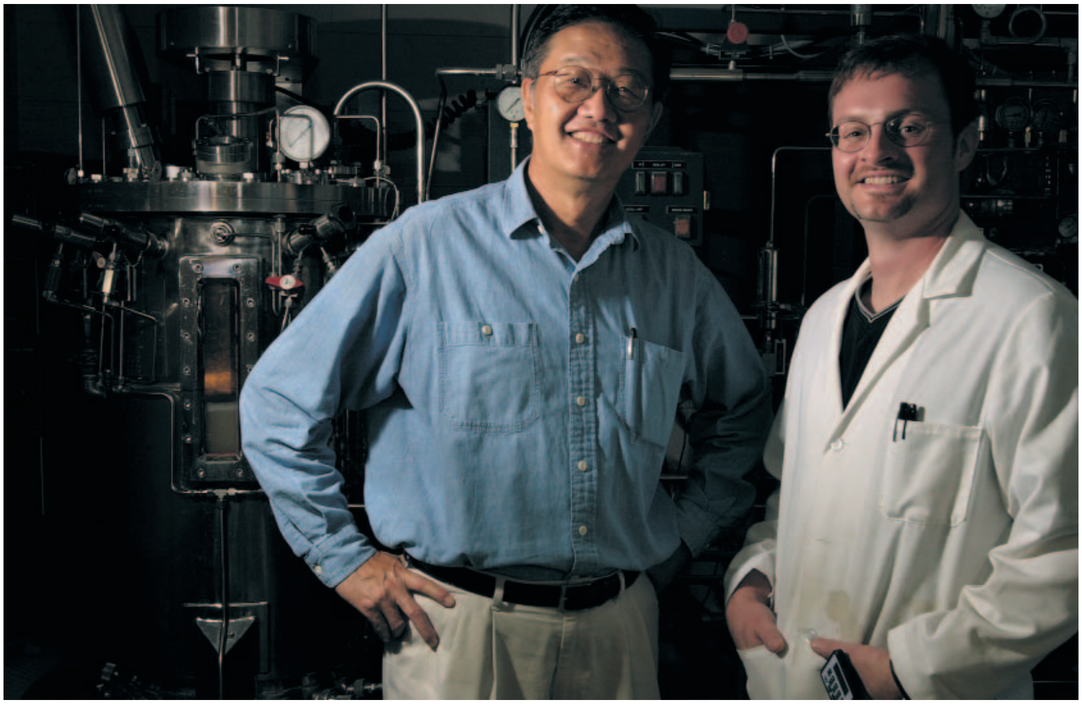
Protein-based plastics are potential rivals for currently available biodegradable plastics, which are made of carbohydrate starches. The American Society for Testing and Materials (which establishes voluntary consensus standards that contribute to the reliability of materials, products, systems, and services) has recently upped the standard for calling materials biodegradable: they must completely decompose into carbon dioxide and water within 180 days. Proteins, which contain nitrogen, naturally decompose into water, carbon dioxide, and nitrogen-containing natural products, so the standards will have to be redefined if protein-based plastics become common. Unless feather fiber–containing plastics are made with biodegradable binders, however, the objects will deteriorate from degradation of keratin, but the nondegradable plastic materials that once bound the fibers together will be left over.

Keratin is hardy enough that feathers, unlike cloth, are often found nearly intact at archaeological sites. Their tough, fibrous structure is poorly digested by most protein-degrading enzymes. But when mixed with manure, feathers degrade well. "When feathers are composted, the by-products produced go back into organic matter in the land, which produces further benefits," says Brian Donnelly, president of Microlife USA, a material recovery company that composts poultry wastes and other materials. "Many national, regional, and local poultry [processors] understand the economic benefits of composting all poultry waste because they can sell it at a tidy profit," says Donnelly. Feathers are a valuable part of the poultry waste compost mix because they add nitrogen, an important fertilizer component.

Production of feather meal, a feed additive, gives poultry processors another way to reuse feathers. Feather meal is produced by a high-pressure steam processing method similar to autoclaving, followed by drying. Heat and steam hydrolyze the feathers into a cysteine-rich, high-protein product that is 60% digestible. But producing feather meal is only marginally profitable because of the cost of moving and processing the feathers, according to the ARS, although there is some market for the product, and poultry producers can make feather meal for their own use.

Jason Shih, a professor of biotechnology and poultry science at North Carolina State University in Raleigh, has found a way to turn feathers into a better feed product. While developing a bioreactor system for converting chicken manure to methane and other by-products, he noticed that stray feathers present in the mix were disappearing. Shih isolated a keratin-digesting strain of the bacterium *Bacillus licheniformis*. This strain is capable of fermenting feathers, breaking their keratin into digestible proteins and amino acids. He has now identified the gene for a keratinase enzyme within the bacterium that actually digests the feathers. Using molecular biology, he has improved the yield of the enzyme, making enough of it to use on its own to break feathers down directly rather than using bacteria.

"Hydrolyzing the feathers [with keratinase] makes them highly digestible," says Shih. Feathers become a value-added product, a higher-quality and thus more expensive feed that may be more profitable for producers. Shih's feather-derived animal feed has more than 80% available protein, a substantial improvement over traditional feather meal. He holds six patents related to the



Feather mountain breakdown. Jason Shih (above left) and research technician Brian Spencer (above right) stand before a machine that produces enzymes that can by used to turn waste feathers into a highly digestible meal used in animal feed. During the conversion process, feathers are washed (right top), chopped (right center), then treated with a keratinase enzyme isolated from the bacterium *B. licheniformis* that ferments them into meal form (right bottom).

enzyme technology and has started a company, BioResources International, that has licensed the technology and is developing more cost-effective mechanisms for isolating the enzyme with an eye toward making a better and higher-capacity processing system, as well as improving the method for purifying the enzyme to make it less expensive. The cost of the feather-derived feed is expected to be competitive with other higher-quality feeds with similar protein value.

The enzyme and the bacteria that produce it could be valuable in breaking down materials made with feather fiber, as well as feathers themselves. "The volume of diapers in landfills is so high," says Schmidt, "if you had diapers made of this material and inoculated the landfills with keratinase-producing bacteria, it could take care of the bulk of the diaper recycling problem."

The Future for Feathers

Widespread use of feather fiber in consumer materials and as a higher-quality animal feed is still in the future. Currently, composting is still the most cost-effective reuse of feathers; the new methods have not yet had much effect on the more than one million tons of feathers produced each year. Neither Schmidt's nor Shih's approach can yet process feathers at the levels required to handle the waste generated by even a single poultry production facility. "Disposal, composting, digesting, and recycling are gaining ground in handling poultry feathers," says Donnelly, "but the sheer volume [of feathers] produced overwhelms current processing infrastructure." With each plant producing more than 65,000 pounds of feathers a day, producers need methods that will solve the practical problem of moving old feathers out to make room for waste from newly processed chickens. Right now, composting and feather meal production are the only reuse methods capable of keeping up with the volume of feathers generated.

Although Schmidt's technology is still scaling up, he expects it to catch on quickly. "This is close to a win/win/win situation for almost everyone involved in the process," he says. The potential profit from feather fiber is high enough that producers who are ahead of the curve with this technology could afford to undercut their competitors on the price of chicken meat. End-user industries and the environment stand to benefit from a constant, renewable, natural source of fiber, while poultry producers could gain increased value from the birds that they are already producing—and plucking—for human consumption. Shih, too, is convinced his method will take hold. "Feathers become a value-added product," he says. "If we can improve the production we've got now to handle tons and hundreds of tons, it will really help the poultry industry." Adds Schmidt, "It's like aluminum cans—you can't have this value in hand and not recycle it."

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Suggested Reading

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