produced from these particular transgenic pigs to be useful for trans-fusion. However, information gained from studying them will be extremely useful for designing subsequent experiments. The next step is to alter human globin genes in such a way that they are crosslinked and have reduced oxygen affinity, enabling them to readily release oxygen to the tissue. A number of laboratories are currently researching this complex problem.

Problems Remain
Even though several human therapeu-tical proteins have now been success-fully produced in the milk and blood of transgenic animals, some difficult problems must be solved before these products are approved for use. Product safety is an important issue. These products will require the same rigorous scrutiny as the products extracted from animal tissue, produced by tissue culture, or synthesized by other recombinant techniques. Products from transgenic animals must be purified to remove all nonhuman pro-teins that might cause allergic reac-tions. In addition, it is still not known whether the complex human proteins produced in transgenic animals have the identical structure and biological activity as the natural proteins pro-duced by the human body.

While scientists are confident that the technical and regulatory chal-lenges can be overcome, few people are willing to predict how long it will take to work out these problems and complete the clinical testing that will be required to obtain Food and Drug Administration approval for marketing.

Innovative Uses of Animal Byproducts

Current Trends in Animal Fats Markets
One of the original recyclers of agricul-tural byproducts is the U.S. render-ing industry. Renderers recycle the growing amount of waste from our huge meat, dairy, and fast-food indus-tries, converting the millions of pounds of byproducts generated daily into not only useful, but essential, products—an estimated annual production of 12 billion pounds of...
rendered products including inedible tallow and grease, edible tallow and meat, and bone meal. (The terms “inedible” and “edible” refer to use as a human food.)

Edible and inedible tallow presentely account for about 6.9 billion pounds of this overall annual production. In recent years, the edible tallow has ranged from 15 to 21 percent of the total output of rendered products. The growth occurred because of increased processing of carcasses at centralized packinghouses and the selective removal of fat from consumer cuts. The net effect of the latter was that the price differential between edible and inedible tallow decreased to about 1 cent per pound.

The major outlet for edible tallow has been as baking and frying fat. Recent U.S. production of edible tallow was 1.2 billion pounds, with increased exports due to decreased domestic consumption.

A large proportion of U.S. production of inedible tallow, 5.7 billion pounds, has also been exported each year; but unlike edible tallow, this amount is shrinking because of a big increase in domestic consumption from the use of fat in animal feed and pet food. This increased use of inedible tallow began in the 1950's when scientists at the Eastern Regional Research Center (ERRC), ARS, USDA, in Philadelphia, PA, showed the high nutritional value of these byproducts in animal feed and pet foods. Today, feed fat accounts for 60 percent of domestic usage, compared with 41 percent 10 years ago. This amounts to over 2 billion pounds of feed fat.

The other major outlets for inedible tallow are in industrial applications, such as the manufacture of fatty acids, paints, varnishes, rubber goods, plastics, and lubricants. Overall, inedible tallow's largest market percentages are 96 percent of the feed market for fats and oils; 32 percent of fatty acids as specialty chemicals; 42 percent of soaps; and 69 percent of lubricants.

**Enzyme-Processed Fats**

The primary constituent of fatty animal byproducts such as tallow and lard is triglyceride, a union of three fatty acids and glycerol. About one-half of the fatty acids are saturated. The other half are composed of oleic acid, a monounsaturated fatty acid that is much prized by both the food industry and the industrial sector; this acid converts fats into consumer and industrial products such as soaps, detergents, lubricants, and adhesives. Studies at ERRC have shown that a class of enzymes called lipases can split fatty acids from glycerol. Specific lipases have been shown to selectively split oleic acid from tallow and lard while leaving the saturated fatty acids bound to glycerol, thus giving industry a molecular tool to harvest oleic acid from animal byproducts.

To understand why an enzyme that splits only oleic acids offers such an exciting opportunity to improve on existing procedures, it is necessary to explain how processing is currently done. Large tank cars containing the fats are heated with steam. The melted fats are pumped into a fatty-acid splitter where heat and superheated steam pressure (to 850 °F) are applied. The
superheated steam splits the fatty acids from glycerol. As the steam cools, it condenses to water, causing separation of water-insoluble fatty acids and water-soluble glycerol. Distillation is used to separate oleic acid from the saturated fatty acids.

This industrial process has many drawbacks. First, heated fatty acids react rapidly with oxygen in air to form a variety of unwanted side products. To reduce this problem, the entire apparatus—splitters, distillers, and reactors—is continuously flushed with nitrogen. Another current problem is the large amount of energy consumed by the industrial splitting process. This large input increases costs and dampens demand.

In contrast to the high-temperature splitting process, the enzymatic or lipase splitting of the oleic acid could be conducted at room temperature. Once the splitting is complete, oleic acid is relatively easily separated from the saturated diglycerides and monoglycerides and glycerol. In many cases, the oleic acid fraction would be pure enough to sell as is. The purity of the oleic acid fraction depends in large part on the specificity of the lipase. Work to find the most specific lipase, either through the screening of natural sources or through the wonders of molecular biology, is ongoing at ERRC.

**Isopropenyl Esters From Fats**

Simple fats and welder’s gas can be processed in the presence of other common materials to form compounds known as isopropenyl esters, which react rapidly with paper and cotton to make them water-repellent. They can also be used in glass coatings that reduce breakage in mechanical bottling operations. Scientists and engineers at ERRC have developed high-yield processes for preparing these chemicals.

Isopropenyl stearate, or IPS, is the most commonly prepared and used isopropenyl ester. Stearic acid, a common fatty acid, is readily extracted from tallow, or beef fat. In the presence of zinc compounds, it will react readily with the major component of welder’s gas, methyl acetylene, to form IPS that is over 90 percent pure. Other isopropenyl esters are made by similar processes.

In making cotton and paper water-repellent, the stearic acid group from the IPS is transferred to the surface of these materials where it becomes chemically and permanently bound. An important benefit of this reaction is that its byproduct is an innocuous water-soluble organic solvent, acetone. Alternative methods produce by-products that are highly acidic and corrosive compounds such as hydrochloric acid. These make quality control difficult and costly and shorten the life expectancy of the equipment used in their application. Cotton can be made water-repellent with only low levels of IPS treatment and suffers very little loss of other beneficial properties; similarly, paper treated in this manner repels water and resists feathering caused by writing inks.

**Soap/Lime-Soap Dispersant Combinations**

Natural soap can be used in hand and bath soaps, as well as in laundry and dish detergents, when combined with
products known as “lime-soap dispersing agents.” In hard water, minerals react with the fatty acid components of tallow-based soaps to produce insoluble materials known as lime soaps that are responsible for ring-around-the-bathtub and other similar problems. Lime-soap dispersing agents selectively and effectively combine with the materials in hard water responsible for the formation of lime soaps but, unlike soap itself, they remain in the solution. Furthermore, they are easily made from the same raw materials as the soap and share its ready biodegradability. Thus, soaps and laundry detergents made with these compounds are safe and easy to use for personal care, as well as being environmentally advantageous.

Scientists at ERRC developed processes for making these lime-soap dispersing agents from readily available tallow, beef fat, and other fatty materials. These compounds are anionic, or negatively charged, surfactants called sulfonated methyl esters of fatty acids. Their basic chemical structure is a sulfonated ester of fatty acids, a compound that has both water soluble and insoluble properties. The watersoluble portion is the sulfur-containing portion of the molecule, and the fatty acid is the water-insoluble portion. Hence, these compounds have the ability to interact with oily grime and dirt while maintaining the water solubility necessary for cleansing and for an easy flow down the drain.

Thus, consumer products that contain natural, safe, inexpensive soap can be made from animal fats and used in consumer products in place of petroleum-based synthetic detergents. In the United States, products containing lime-soap dispersing agents are

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Collagen Products
In the past 15 years, many attempts have been made to find new applications for the unique physicochemical properties of collagen, a protein derived from animal skins and hides. Nevertheless, gelatin and fibrous edible collagen sausage casings continue to be the two most important commercial outlets, besides leather, for this material.

Hydrolyzed collagen is incorporated in many cosmetic products. Medicinal-grade collagen is currently being marketed as soluble, injectable collagen; devices to reduce bleeding; wound dressings; and tissue repair material. These products are used in general surgery, dentistry, ophthalmology, dermatology, and other medical fields. Currently, the most publicized use is the subcutaneous implantation of soluble collagen for the correction of dermatological defects.

Research in the use of collagen has led to a wide range of applications. Chemically modified collagen for hemostatic work, for example, has enhanced the ability of this protein to absorb fluid while reducing stimulation of the immune system. In the design of fibrous collagen products, the strength of the reconstituted materials is often increased by joining the collagen fibers to each other through chemical bonds. One of the more promising techniques in medicine is the immobilization of enzymes or cells onto collagen matrices for selected removal of disease-causing tissues.

The medical applications for collagen developed in recent years are quite impressive. However, it is the basic knowledge about collagen’s chemical and physical properties and the increased understanding of its interaction with human tissues that are inspiring further accomplishments in the protein’s use.

Consumer products that contain natural, safe, inexpensive soap can be made from animal fats and used in place of petroleum-based synthetic detergents. In the United States, products containing lime-soap dispersing agents are Lever 2000 (Lever Brothers) and Zest (Proctor and Gamble).
Blood and Blood Fractions

Blood is a natural byproduct of the beef and pork meat industries and represents a substantial source of underused, readily digestible, high-quality protein. The plasma fraction that makes up 50 percent of the blood volume has a protein content of about 7 percent, while the red blood cell fraction contains 38 percent protein. Currently, the primary use of this blood has been in the animal feed industry. However, only a small amount of the blood has actually been used by the food industry because of the liquid’s instability, its high water content, and food safety concerns. In addition, the red coloration and the smell of blood have been considered negative factors preventing a broader use by the food industry.

Today’s food-processing technologies have significantly increased the potential for blood’s use by the food industry. Current methods of preservation, fractionation, and drying of the plasma and red cell fractions now yield products that can be used in sausages and other processed meat products such as sandwich cold cuts. Plasma proteins have good gel-forming properties and good water- and fat-binding properties that permit plasma’s incorporation into sausage products at levels up to 10 percent. Similarly, the red cell fraction can be used directly in certain processed meat products where the red color contributes a positive quality to the final product. Removal of the heme pigment from hemoglobin by chemical or enzymatic methods produces a decolorized product that can also be used in processed meat products. At present, protein fractions derived from blood are available for use by the food industry.