A New Fiber From Corn Kernels

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From the corn kernel we now get a fiber that combines good qualities of cotton and wool. Fabrics made from it are durable, warm, and washable.

The starting material is zein, a relatively pure protein that is separated from the starch, oil, and other parts of the seed. It looks like discolored flour and is converted to fiber by complicated processes. The method, developed at the Northern Regional Research Laboratory, was announced late in 1945 and was so successful that it was in commercial operation in 1948.

Zein is isolated from corn-gluten meal, a byproduct of starch refineries, by alcoholic extraction. It is marketed as a dry, yellowish powder, which can be stored for long periods without appreciable change. It is soluble in the usual prolamine solvents, such as aqueous alcohols, ketones, and organic acids, and in alkaline solutions at a pH range of 11.5 to 12.5. Because of its unique properties, zein also is in demand for other industrial uses—in varnishes, plastics, and adhesives, for instance.

Fiber can be spun from zein solutions by either dry- or wet-spinning techniques. The dry-spinning method is copied from the spider or silkworm and is like the process used to make acetate rayons. The spinning dope is a clear, thick solution of material in a volatile solvent, such as alcohol or acetone. It is pumped through extremely small holes punched in the bottom of a metal cup called a spinneret. The spinneret is held at the top of a column of hot air; as the fine stream of spinning dope from each hole falls through the column, the solvent evaporates, leaving solid filaments, or fibers, which are collected at the bottom.

The wet-spinning process is like the one used for making viscose rayon. The spinneret is held below the surface of a water bath, which usually contains acids for solidifying the spinning dope as it comes through the holes in the spinneret. The solidified filaments are gathered together as a wet tow, which is processed on reels and in baths before being dried.

Theoretically, zein fiber can be spun from volatile solutions by either method. Patents cover processes for both, but there have been no successful commercial applications of them.

A more recent process developed at the Northern Laboratory has been more successful. Its operation was on only a small scale but was continuous, rather than batch. The basic principles are used commercially. A wet-spinning process, it uses alkaline dispersions (solutions) of zein as the spinning dope. Strengthening and hardening treatments of the newly formed filaments are necessary before they become suitable textile fibers.

Alkaline spinning dispersions consist primarily of about 1 part alkali, 50 parts zein, and 330 parts water. The alkali (sodium hydroxide) is necessary to make the zein dissolve in the water. Other substances may be added to the mixture for various reasons—for example, oils to soften the fiber, or a chemical, such as urea or alcohol, to hasten denaturation, the physical change necessary for satisfactory spinning.

The dispersions are easily prepared

if a few precautions are observed. The dry zein is first mixed in about three-fourths of the water, which preferably is precooled. If the temperature of the mixture rises much above normal room temperature, we get a doughy mass, which is difficult to work. The alkali and urea dissolved in the remaining water are then slowly added to the mixture, which is stirred until a clear, uniform dispersion results. Enough alkali must be present to bring the final pH up to near 12.0; an excess of alkali causes the zein to come back out of solution if the pH goes above 12.5.

Good spinning dispersions are essential for good fibers. There must be no undissolved particles or air bubbles in the dispersions. Anything that momentarily interrupts the flow of dope through the spinneret holes causes unsightly, detrimental breaks in the fiber. The best spinneret action is obtainable by using spinning dopes of relatively high viscosity, like thick molasses. The high viscosities result either from using high concentrations of zein or from aging dispersions of lower concentration. A convenient method is to prepare dispersions of low protein concentration, which readily pass through filters and from which the air readily rises. Then, while aging in the presence of denaturing agents, the viscosity gradually increases to the desired value.

When the dispersion has attained suitable spinning characteristics, it is forced by a metering pump through the holes of the spinneret into the acid coagulating bath. A satisfactory bath consists of 87 percent water, 5 percent sulfuric acid, 3 percent acetic acid, and 5 percent zinc sulfate.

The size and number of holes in spinnerets vary, depending on the desired size of filament and the ultimate use of the fiber. A spinneret containing about 40 holes is ordinarily used to make continuous-filament yarn. One with as many as 12,000 holes is used to make another type that is ultimately cut into short pieces before being carded and twisted into yarn. All the filaments from one spinneret are pulled out of the coagulating bath in the form of a rope, called tow, by passing over a revolving reel. The tow then runs continuously over reels and through treating baths until at the end it is separable into the dry, finished fibers.

The freshly coagulated filaments are tender and weak and must undergo special treatments to form useful fibers. The three essential treatments are a mild cure with formaldehyde, a high stretch in hot water, and a stronger formaldehyde cure of the stretched fiber.

The first formaldehyde cure is carried out on the slack fiber in a bath immediately following the coagulating bath, or the two baths may be combined. The first cure is important in toughening the fiber so that it will withstand subsequent handling. It is also important for imparting strength to the fiber. The formaldehyde probably ties the zein molecules together, so that the ensuing hot-water stretch is effective in orienting the molecules into a desirable fibrous pattern. The stretched fibers are strong, but have rubbery characteristics; that is, when the tension is released, the wet fibers return to their unstretched length. A drying of the elongated fibers temporarily stabilizes their length, but whenever the fibers again come in contact with water, the shrinkage occurs. The shrinkage, especially in hot water, prohibits the use of the fiber at this stage in textiles and other applications.

The second formaldehyde cure is applied to the stretched fiber. Its purpose is to stabilize permanently the fiber against shrinkage. The role of the formaldehyde is to form bridges, or cross-bonds, between the protein molecules, thereby holding them in an oriented state. It is desirable to form cross-bonds that are resistant to the boiling acid used for dyeing wool.

This second formaldehyde cure is conducted either in a water solution while holding the wet stretched fiber at constant length or in a nonaqueous system on dry fiber. When the curing is in an aqueous formaldehyde system, the most stable bonds are formed in solutions that contain a high concentration of hydrochloric or sulfuric acid. The nonaqueous cure consists of formaldehyde or a formaldehyde-yielding agent and a strong acid in an organic solvent, such as toluene or Stoddard's solvent. The treating temperature is about 212° F. The dry fiber does not shrink appreciably during treatment, even when left loose in the mixture. The cure is rapid and effective in producing a fiber stable to boiling acid.

An acetylating treatment with acetic anhydride has been used to good advantage on the fiber. It is applied between the two formaldehyde cures. It is not effective in preventing shrinkage, but improves such properties as water resistance, color, affinity for dyes, and softness of the fiber.

After it has been given its first formaldehyde cure, stretched to just short of breaking, and dried, zein fiber is exceptionally strong, wet or dry. The second formaldehyde cure eliminates the undesirable shrinkage, but does so at a sacrifice in strength of the fiber—especially when the wet cure is used. The stabilized fiber, however, is still as strong as wool, and, because it is proteinaceous, it has the desirable woollike properties of water absorption and resilience. Resilience involves the degree and rate of recovery after a distorting force has been applied. These properties are the main contributors to the wrinkle-resisting and crease-retaining character and to the warmth of wool fabrics. Zein fibers are flexible, although they contain no plasticizer, which might change with age or be washed out in laundering. They also have acceptable extensibilities, a good feel, and dye nicely with a variety of dyes.

The fiber, like all other protein fibers, is expensive in comparison with cellulosic fibers like cotton or rayon. On the other hand, it is cheaper than wool. It can meet competition with our other good fibers because of its unique combination of properties.

Anticipated uses for the fiber are in woven and knitted fabrics in which it will be used alone or blended with other fibers; in felts as a partial replacement of fur; and in brushes, in which bristle stiffness is gained by a larger size of filament.

Commercial production of zein fiber is actually in its infancy, although many years of research have gone into the making of fibers from proteins such as from peanut, milk, soybean, and corn. The Virginia-Carolina Chemical Corp. of Richmond, Va., began an investigation of high polymers from protein bases in 1939. Through the basic work done at the Northern Regional Research Laboratory, they investigated zein fiber and found it to be most suitable for a new textile-fiber development. As a result, Vicara came into commercial production in 1948.

It is known as the "fiber that improves the blend." It adds suppleness and draping qualities to rayon, warmth and absorptiveness to nylon, and softness to wool.

The blending, yarn spinning, and weaving are easily carried out in conventional machinery. It is readily dyed by most known methods and, because of its combined acid and alkali resistance, withstands better than other fibers, all textile processings. It burns slowly and is inherently moth- and mildew-resistant. When used alone or blended with other washable fibers, it is readily washed without any special precautions.

Zein fiber is a made-to-order "wool." The quality of the product is uniform and the fineness or coarseness of the fiber can be controlled to best fit the purpose at hand. Other properties can be controlled to enhance its ability to stand alone or to improve the blend. Fabrics made from it are as warm as wool, yet nonitching and launderable.

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