Flexible nonwoven composites for food packaging

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ABSTRACT *At a time when food-packaging technology is demanding increasingly sophisticated laminated films, one time-proven cellulose composite remains the material of choice for a specific area of food packaging. This flexible, nonwoven composite—commonly known as "sausage casing"—possesses unique characteristics of high strength, low elongation, semipermeability to gases and liquids, and heat stability. Cellulose fibrous casing composites also can be modified chemically for use in drug and chemical purification applications.*

KEYWORDS
Cellulose
Cellulose fabric
Composites
Flexible packaging
Food storage
Nonwovens
Polymer paper combinations

Flexible cellulose films have a history of successful use in food-packaging applications. There are two types of cellulose films: a clear, transparent, regenerated "cellophane"-type film, and a nonwoven, fibrous, paperlike film.

The transparent cellulose films are produced using a rayon cellulose xanthate derivative that is extruded to produce a regenerated pure cellulose. The fiber-reinforced cellulose films are a composite of cellulosic fibers and a suitable moisture- or heat-insensitive binder, such as regenerated cellulose. Nonwoven cellulose webs can be bonded to produce fibrous films with a wide range of physical and chemical characteristics. The requirements for strength, uniformity, and barrier properties continue to change with the evolving packaging technology. As a result, the flexible composites used in food packaging are specifically designed for their individual applications.

"Sausage casing" is the common name for a flexible fibrous composite that is used in a variety of packaging applications. The nonwoven web is often made of long-fibered abaca hemp, which is noted for its strength. Webs are also produced using other high-tenacity fibers such as sisal and flax (*1*). The nonwoven material is formed into a tube and bonded with a cellulose xanthate (viscose) solution. Upon removal of the xanthate group (regeneration), the casing is generally purified and dried using the process described in **Fig. 1**.

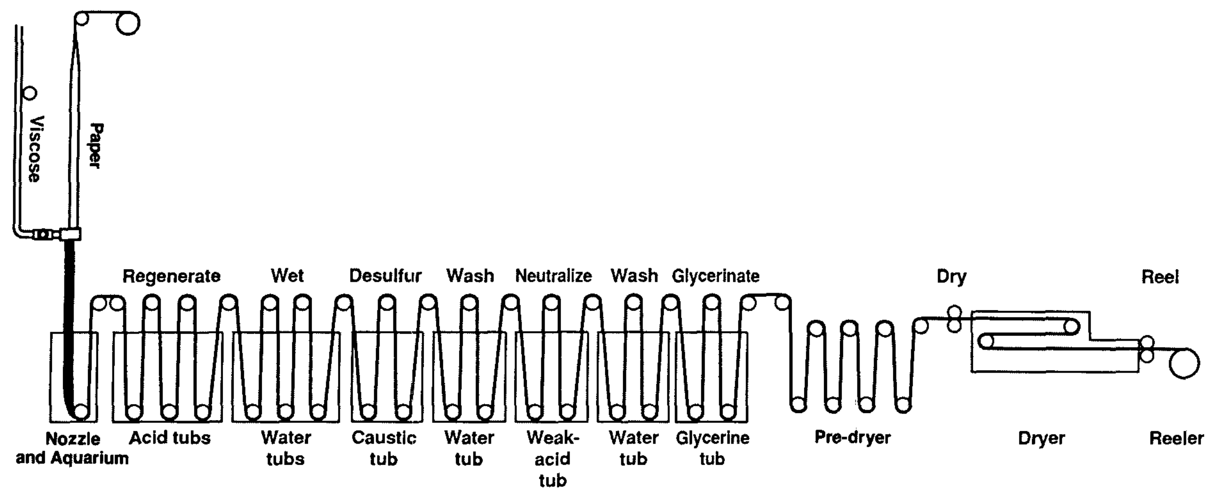
The resultant tubular casing is a composite material containing natural abaca hemp fibers embedded in a matrix of regenerated cellulose. The composite is stronger than either component and owes its superior strength to the unique construction. While the composite material is predominantly produced as a tubular casing for processed food packaging, it can be slit for sheet application as well. The bonding media can be applied single sided or from both sides of the nonwoven substrate (*2*, *3*), and tubular extrusion allows biorientation of the film. The result is a fibrous casing composite with unique characteristics.

Alternative constructions

The basic construction of fibrous composite casings can be modified in several ways. The nonwoven fiber base can be made of various natural or manufactured fibers. Depending upon strength and/or economic requirements, other cellulose fibers (wood and cotton) or hydrocarbon-based spun-bonded fibers (nylon and polypropylene) can be used as substrates. However, performance and cost are not the only considerations in the choice of a substrate. Any raw material to be used in food packaging also must be approved by the FDA (Food and Drug Administration). Obviously, this requirement restricts the choice of web substrates. **Table I** shows the Mullen burst values for casings prepared from several approved nonwoven webs at comparable basis weight.

The bonding matrix need not be regenerated cellulose, but again the choice of polymeric binder must have the proper FDA and USDA (United States Department of Agriculture) approvals for the food-packaging

1. Production of fibrous casing



application. Several workers have investigated alternative polymers for the bonding matrix, i.e., starch, cellulose carbamate, imidazoline derivative, and other cellulose solvents (4-7). Regenerated cellulose from cellulose xanthate remains the binder of choice for production of fibrous composite casings.

Other factors that influence the choice of the nonwoven substrate and the polymer binder matrix are processability and mutual compatibility. A fibrous web that cannot be easily impregnated with the binder matrix will not process well. Weak spots caused by incomplete bonding will render the casing unacceptable for use as a packaging material. If the surface energy of the fibrous web is such that the polymeric binder matrix does not thoroughly "wet" the nonwoven, the lack of intimate contact between the web and the binder will result in a poor fiber-to-polymer matrix bond, and the composite will not have the required strength. Finally, if the elongation characteristics of the nonwoven web and the polymer matrix are vastly dissimilar, the composite structure will fracture when subjected to stress.

Casing structure and characteristics

The fibrous casing is a composite structure and not a simple laminate. This is best illustrated by the scanning electron micrographs (SEM) in **Figs. 2-6**. Figure 2 shows the fiber structure of the nonwoven web used in the composite. The two-sided nature of the casing is illustrated in Figs. 3 and 4, which show the exterior and interior surfaces, respectively, of a casing with the viscose applied on the exterior surface. Figure 4 shows that the binder is in contact with almost all of the fibers on the surface opposite the side of binder application.

The smoothness of either the interior or exterior surface can be altered by the method of application. If viscose is applied from one side and pressed through the web, a slightly rougher coat is formed on the opposite surface. If the viscose binder is applied from both sides, the regenerated cellulose provides a smooth, even coat over the fibrillar structure, as seen in Figs. 5 and 6.

Cellulose fibrous casing composites are semipermeable to gases and liquids, an important criterion in food-packaging applications. The casings also possess molecular size selectivity.

I. Wet Mullen burst pressures* for casings with different nonwoven substrates at comparable basis weight

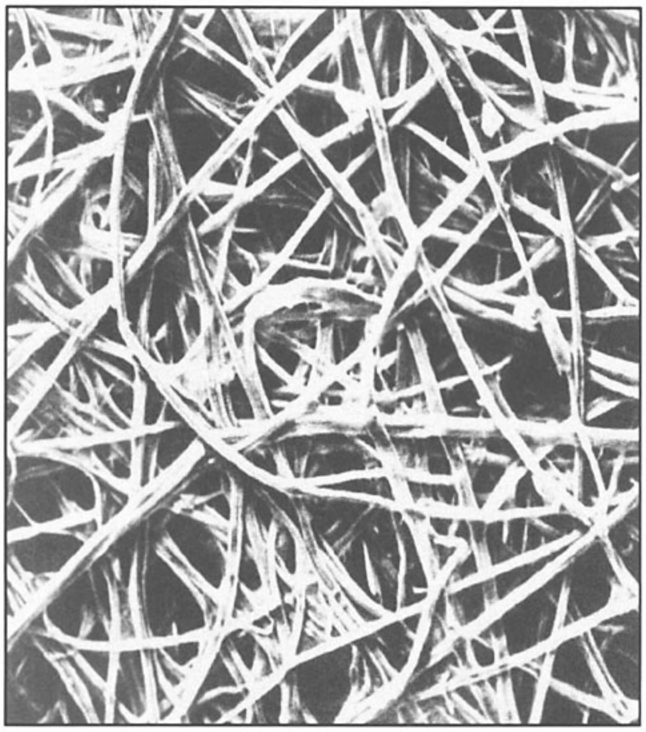
Nonwoven substrate	*Burst per unit of basis weight, kPa/g/m²*
Abaca hemp (C.H. Dexter Corp.)	10.6
Spun-bonded nylon (CEREX, James River Corp.)	12.3
Spun-bonded polyester (Remay, Dupont)	4.7

*Mullen burst determined using ASTM D774.

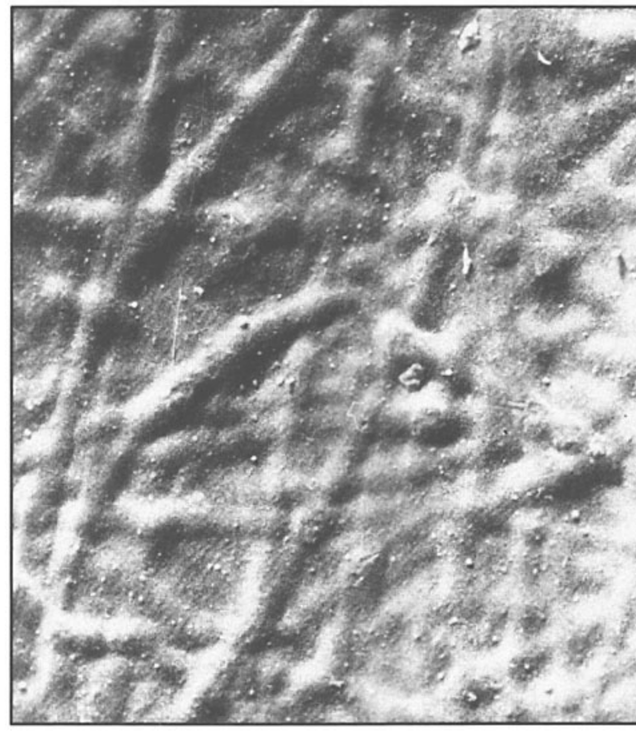
Chemical species less than 12,000-14,000 molecular weight pass readily through the casing membrane. This characteristic is an asset in food-packaging applications as well as in other nonfood, membrane-type applications.

The moisture permeability of the fibrous composite changes, depending on whether it is wet or dry. **Table II** shows moisture-vapor transmission for a typical casing in both wet and dry states. Because moisture can pass through readily to the ambient air, a composite casing can be used to dry

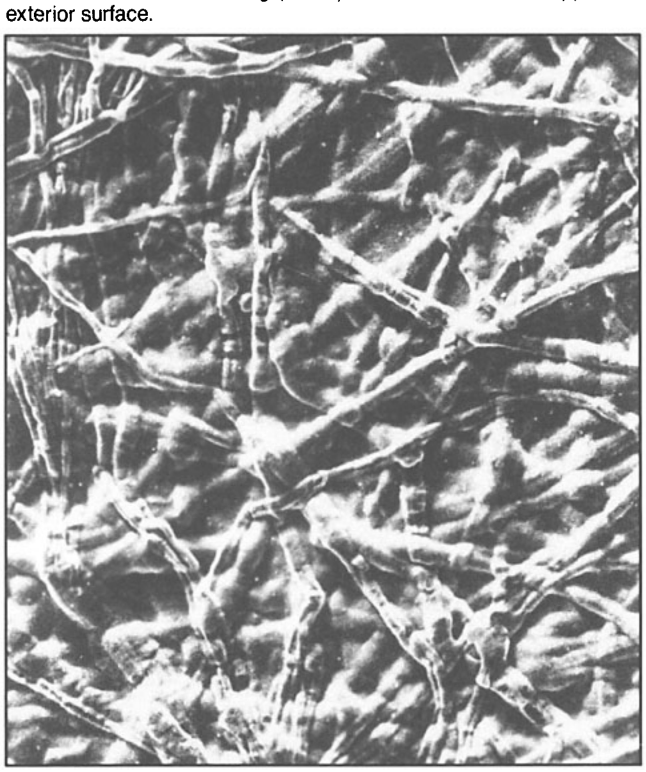
2. Nonwoven web prior to application of viscose binder (100 ×)



3. Exterior surface of casing (100 ×). Viscose binder was applied to exterior surface.

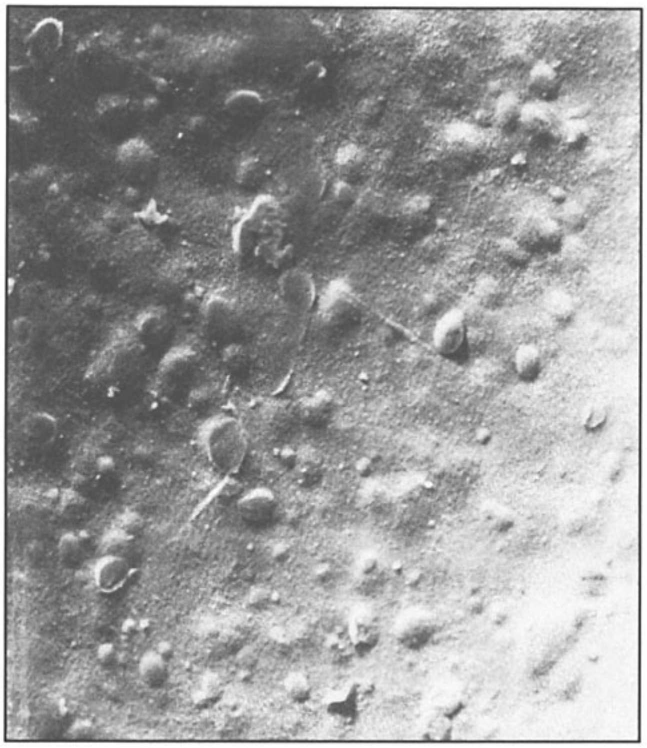


4. Interior surface of casing (100 ×). Viscose binder was applied to exterior surface.

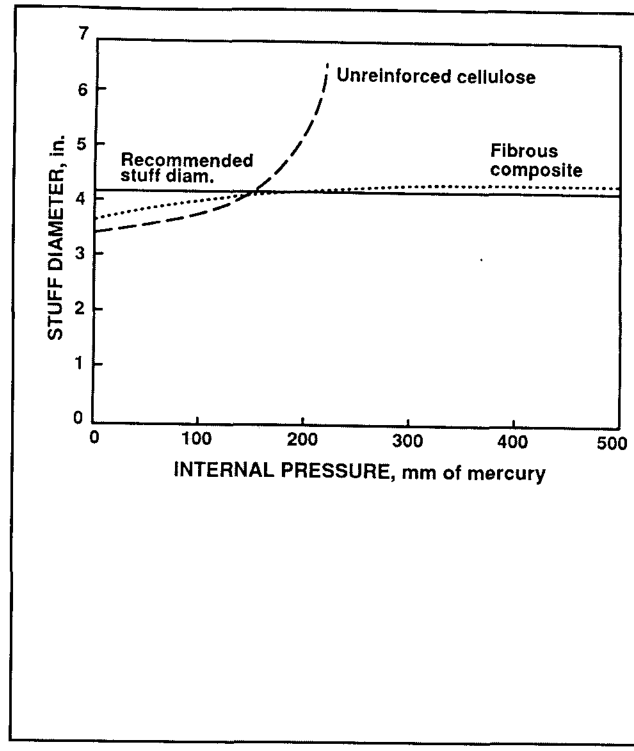


5. Interior surface of casing (100 ×). Low level of viscose binder was applied to interior surface.

6. Exterior surface of casing (100 ×). High level of viscose binder was applied to exterior surface.



7. Casing diameter as a function of internal pressure for fibrous composite and unreinforced cellulose film.



II. Moisture-vapor transmission rate for wet and dry fibrous casing

	Moisture-vapor transmission, g/m²/24 h/atm*
Wet casing	12,700
Dry casing	2,300

* Moisture-vapor transmission rate determined at 100°F using ASTM E9666.

III. Wet tensile strength and wet elongation for three commercial casings

Film type	*Thickness, mil*	*Wet tensile strength,[a] kN/m* — *Machine direction*	*Cross-machine direction*	*Wet elongation,[b] %*
Fibrous composite[c]	3	2.8-3.5	2-2.5	20-40
Plastic film[d]	3	...	5-6	150-200
Paper[e]	2-3	...	0.4-0.6	5-10

[a] Wet tensile strength determined on an Instron tester using ASTM D828.
[b] Wet elongation determined on an Instron tester using ASTM D3759M.
[c] Fibrous casing (Viskase Corp.).
[d] Perflex 52/HD casing (Viskase Corp.).
[e] Casing paper made of abaca hemp (C. H. Dexter Corp.).

moist foods such as salamis. Conversely, a dry casing protects dried products from picking up moisture.

Permeability is a critical characteristic dictating a casing application, but strength and stretch uniformity are equally essential criteria. Most fibrous casing composites are approximately 3 mils in thickness. **Table III** presents wet tensile strength and wet elongation at breaking for three casings: a typical fibrous casing, a casing made of heavy-duty plastic film, and a casing made of paper from abaca hemp. The fibrous composite is quite strong—in the realm of plastic film—yet has low elongation, which makes it suitable for packaging where dimensional uniformity is required. Unlike most of the synthetic films that are used for food packaging, cellulose is relatively unaffected by cooking temperatures up to 200°F and continues to possess uniform stretch characteristics at elevated temperatures.

Cellulose film, including the fibrous composites, must be plasticized with moisture and a polyol (e.g., glycerine). If the film is not plasticized, it becomes brittle and suffers a loss in performance.

Figure 7 illustrates the difference in packaging performance for a casing made of unreinforced cellulose and a fibrous composite casing. The composite casing clearly shows superior strength and uniform performance over a range of stuffing pressures.

Modified casings for new applications

While food packaging is the major application for fibrous casing composites, the semipermeability of these materials makes them suitable for use in purification systems, including dialysis and ultrafiltration. In purification applications, the nonwoven web supplies strength, while the cellulose matrix serves as the molecular filtration medium. Cellulose materials also are used as electrode separators in batteries, an application suitable for a nonconductive, permeable material.

All fibrous composites must be tailored somewhat to meet the specific end-use requirements of a given application. This tailoring varies from color and size to functional chemistry on specific surfaces. Colors are obtained with nonleachable, permanent colorant pigment systems including black, white, red, orange, yellow, brown as well as clear. Product is supplied in tubular form, in rolls, cut lengths, and in shirred/pleated compressed form for compact storage of maximum length.

The composite may contain several polyol plasticizers in addition to regenerated cellulose. Electro-grade material must be free of plasticizers to avoid poisoning the electrodes. In addition, some of the available surface chemistries are based on cationic and hydrophobic resins (*8–13*). The specific application dictates the treatment and its location. A laminate also can be produced by coating the casing with a barrier film of polyvinylidene chloride copolymer. These laminates are used in applications where moisture and oxygen barrier are required (*14*).

Conclusion

Cellulose sausage casing is a practical application for a nonwoven fibrous composite. Traditionally used in food packaging, the material also has found application in other areas because of its unique characteristics of permeability, high strength, low elongation, and heat stability. Because of the nature of the cellulose molecule, it can be readily modified chemically by any of a variety of reagents reactive to the cellulose hydroxyl functional groups. Such flexibility allows the cellulose composite to be used in a wider range of applications.□

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Received for review Feb. 6, 1990.

Accepted Jan. 7, 1991.

Presented at the TAPPI 1990 Nonwovens Conference.