Properties of Southern Pine Needles

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ABSTRACT. To investigate properties that might be related to utilization, needles were sampled on one tree of each of the four major species. Tensile strength was measured on loblolly needles only; it ranged from 4,630 to 6,980 psi. Maximum load averaged 4.1 pounds per needle, with a modulus of elasticity of 220,000 psi. Specific gravity (ovendry weight, green volume) of individual needles of the four species varied from 0.34 to 0.45. Upon drying, loblolly pine needles averaged 1.58 percent longitudinal shrinkage; longleaf, 1.65; shortleaf, 1.85; and slash, 2.31. Total ash for loblolly needles was 3.46 percent. Green moisture content (dry weight basis) was: loblolly, 97 percent; longleaf, 112; shortleaf, 122; and slash, 121. Heat of combustion was 9,030 Btu per ovendry pound in specimens with an alcohol-benzene extractive content of 28.8 percent. Fibers up to 5 mm in length (usually 1.2 to 3 mm) were observed in macerated tissue.

DURING A NORMAL YEAR, needle fall from a southern pine tree may equal or exceed the weight of wood added to the stem. Thus, the foliage comprises a considerable amount of readily available fiber. The utilization potential of southern pine needles, however, is as yet undetermined. In the hope of providing information helpful in planning utilization studies, this paper describes needle anatomy and reports limited data on physical and chemical properties. The intent is not to characterize the species but merely to indicate an approximate range of properties to be expected.

Past Uses

In the late 1800s and early 1900s, a small pine needle industry functioned in the South and the West. Fiber was produced by boiling needles in alkaline solution and carding; yields were as high as 50 percent. Textures varied from a fine wool-like product to one resembling hemp. The strong elastic fiber could be spun, felted, or woven; it was used for surgical dressings, medicated underclothing, carpets, coarse matting, and other textiles as well as for upholstering, mattress filling, and felt production. By 1896, 29 looms had been installed to use the fiber (Mohr 1896). Unfortunately, specific characteristics of these materials are incompletely described. Pine needle oil was

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steam-distilled for use as a scenting agent and for medicinal preparations (Mohr 1896, Record 1916, Mississippi Forests and Parks 1936). Unstable local supply conditions and increased labor costs probably caused the decline of this industry. Today pine needles are used only as mulch and by local craftsmen in weaving decorative trays and baskets.

Literature

Most literature on southern pine needles is confined to physiological studies. Moisture, dry matter, and ash content have been in' gated by various researchers. Reported ı ture contents range from 100 to 300 perce ovendry weight; ash contents of 1.2 to 4.1 cent are reported. Caloric value of ne from some species has been determine Hough (1969) and Madgwick (1970). Li data on organic composition may be four Schorger (1914), Meyer (1928), He (1945), Bailey (1948), Takahashi (1960) Barnes (1962). Information on other pr ties is lacking.

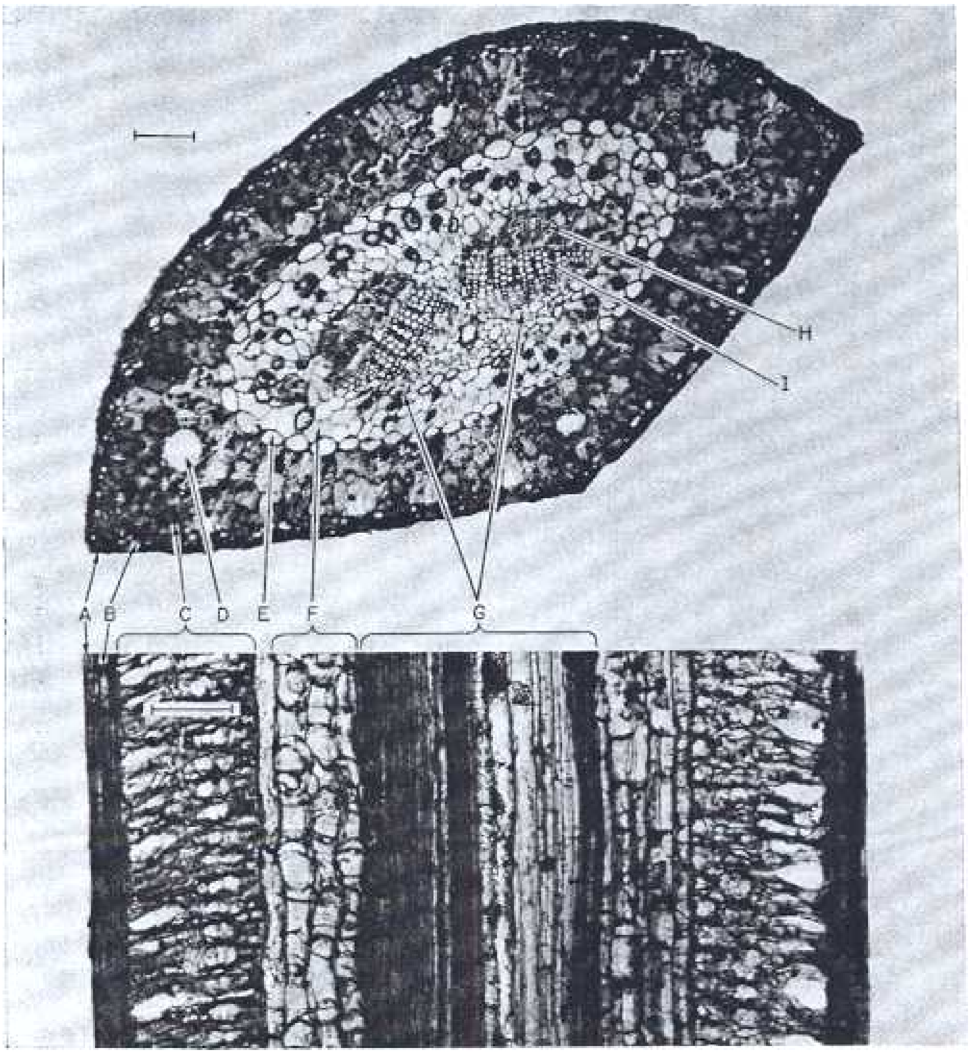

Figure 1. — Cellular structure of southern pine needles. (Top) Cross section, pitch pine. (Bottom) Longitudinal section, longleaf pine. (A) Epidermis. (B) Hypoderm. (C) Mesophyll. (D) Resin canal. (E) Endoderm. (F) Transfusion tissue. (G) Vascular bundles. (H) Phloem. (I) Xylem. Scale marks show 0.1 mm.

Anatomy

A pine needle has a hard, fibrous outer shell, a delicate interior, and a fibrous central core. The various tissues are illustrated in Figure 1. The outer protective layer, or epidermis, is composed of somewhat elongated cells with a thick external coating of waterproof material. Sunken stomata (Fig. 2) are arranged in longitudinal rows on all surfaces and provide gaseous exchange with the atmosphere. Other than the attached base, these openings are the main avenues for penetration of the intact needle. Beneath the epidermis is the hypoderm—several compact layers of long, thick-walled, fiberlike cells that give rigidity to the needle. The mesophyll is a fairly uniform tissue containing chlorophyll and arranged with intercellular spaces. Its small, thin-walled cells have peculiar involutions of the walls projecting into their lumens. Resin canals (two to 10 in number) are located in the mesophyll. They extend the length of the needle but are not connected with resin canals of the stem. The resin canals are surrounded by thin-walled, secretory epithelial cells and long fiberlike cells.

The endoderm—a single layer of somewhat elongated cells with slightly thickened walls—forms a boundary between the mesophyll and the vascular portion of the needle. Just inside the endoderm is the transfusion tissue, which surrounds each vascular bundle. This tissue contains thin-walled parenchyma cells and thick-walled tracheids of varying dimensions.

In the center of each needle are two parallel vascular bundles, each comprised of phloem (toward the outer surface) and xylem (toward the fascicle axis). A vascular cambium separates the two tissues.

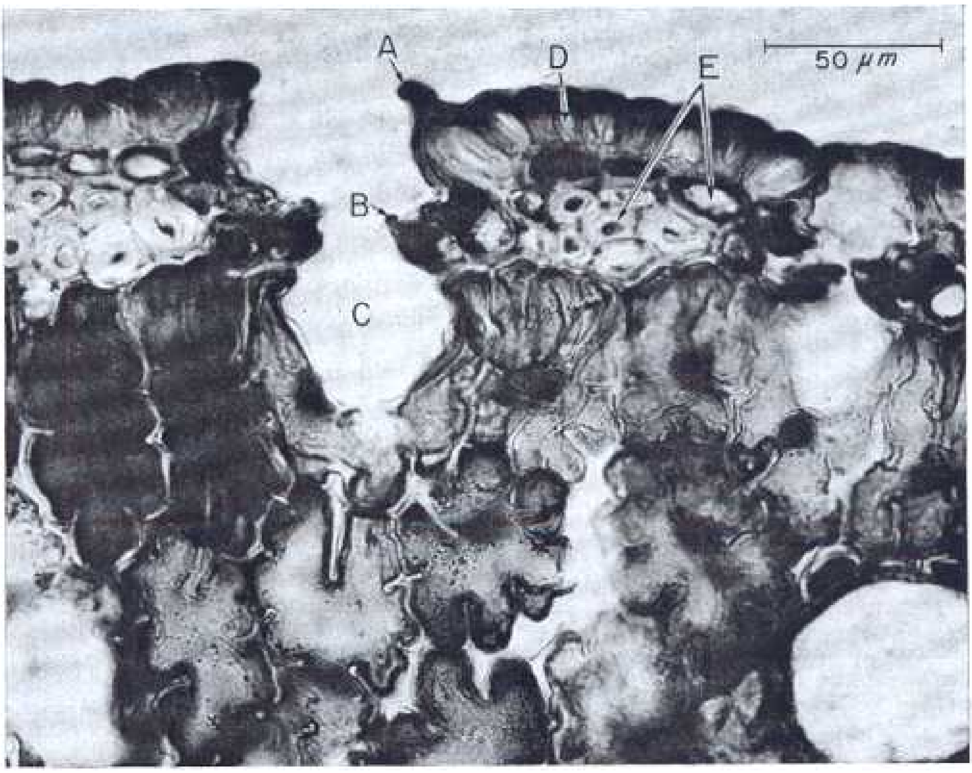

Figure 2. — Open stoma cut through the center in transverse needle section. A closed stoma and a resin canal are at the extreme right. (A) Subsidiary cell. (B) Guard cell. (C) Substomatal chamber. (D) Epidermis. (E) Hypoderm. Table-Mountain pine.

Figure 3. — Macerated tissue of loblolly pine needles. Thick-walled and thin-walled fibers as well as shorter cells are evident. Scale mark shows 0.5 mm.

Figure 3 illustrates some of the cell types found in needles. Of particular interest are the long fiberlike cells, approximately 1.2 to 3 mm in length (occasionally cells as long as 5.1 mm were observed). These fibers are comparable in length to wood tracheids.

Needle Properties

Materials

Needles from one tree of each of the four major species—loblolly (*Pinus taeda* L.), longleaf (*P. palustris* Mill.), shortleaf (*P. echinata* Mill.), and slash pine (*P. elliottii* Engelm. var. *elliottii*) —were sampled for longitudinal shrinkage, specific gravity, green moisture content, and maceration observations. Tensile strength and ash content were determined on loblolly pine needles. Heat of combustion and extractive content were measured on a composite sample from all four species.

The trees were selected on a site with Beauregard silty loam soil. One 35-year-old tree of each species was felled and two limbs were removed from opposite sides at three heights—upper, middle, and lower crown. All needles ' removed from each limb and placed in a pl bag. A small amount of water was sprinkled each bag, and samples were refrigerated until were made. Contents of each bag were m before each sampling.

Measurements

Fifty loblolly pine needles were conditic for three weeks at 72°F and 50-percent rel humidity. A universal testing machine used to measure tensile strength parallel to needle axis of 1-inch-long specimens cut f the center of each needle. Each end c sample was glued between two 1/2-inch n card squares; 0.5-inch of specimen was between the two pairs of squares. After sp mens had been loaded to failure, the c sectional areas were measured under a mi scope fitted with an eyepiece micrometer g

Specific gravity was determined for needles from each of the four trees. G volume of the entire needle bundle (inclu fascicle sheath) was determined by water placement from a pycnometer; samples ' then ovendried and weighed. (Previous t had shown no water uptake during s immersions.)

Four 10-g samples of needles were wei green and again after being dried 24 hou 102°C. Moisture content was expressed percent of ovendry weight. The percent longitudinal shrinkage (based on green len was determined by measuring 20 needles tree when they were green and again w they had dried 24 hours in 102°C oven.

Heat of combustion was determined fr mixed sample composed of equal weights f one tree of each of the four major spe Caloric value of the ovendry needles was m ured with a Parr adiabatic oxygen bomb orimeter. The alcohol-benzene extractive tent of the samples was determined accor to TAPPI Standard T6os-59.

Total ash was evaluated on four gro samples of loblolly pine needles, with ; replications from each sample. Approxim 1.1 g of air-dry sample was placed in previously ignited and weighed cruc Crucibles with samples were ovendried, weighed. Five ml of concentrated nitric was used to digest each sample. Crucibles ' then ignited in a muffle furnace at 480°C for 6 hours, cooled, and weighed. Ash content was expressed as percent of ovendry weight.

Needles of each of the four major species were macerated by Franklin's method (equal parts of glacial acetic acid and 6-percent hydrogen peroxide). Treatment at 60°C for 1 week was necessary, as some tissues were difficult to separate. Macerations were then washed, stained, permanently mounted, and examined to ascertain the cell types present and their relative sizes. Temporary longitudinal and cross sections were also prepared for study.

Results

Results of the various tests are given in Table 1. Because sampling was limited, these data cannot be considered as averages for the species.

As would be expected from the heterogeneous structure of the needle, tensile strengths were somewhat lower than for microtensile specimens of earlywood (7,500 to 9,000 psi, Manwiller 1972). Needles were much more flexible than wood and bore an average maximum load of 4.1 pounds per needle.

Longitudinal shrinkage, ash content, heat of combustion, and extractive content were all greater for needles than for southern pine wood. Both moisture content and ash would be expected to vary considerably with local conditions. Needles ranged from 94 to 139 percent in green moisture content and from 0.34 to 0.45 in specific gravity. Longitudinal shrinkage varied from 1.58 percent (loblolly) to 2.31 percent (slash pine). Shrinkage for whole needles was substantially greater than for wood (usually less than 0.5 percent), but properties of individual needle fibers may differ in this respect.

One noteworthy feature of needles is their limited area of permeability to moisture, which under most conditions would be confined to

Table 1 PROPERTIES OF SOUTHERN PINE NEEDLES (VALUES FROM 1 TREE PER SPECIES).

Property	Average	Range
Ultimate parallel tensile stress, loblolly pine (psi)		
Max. load (pounds)	4.1	3.0 - 5.2
MOE (psi)	220,300	167,400 - 277,800
Green moisture content, dry weight basis (%)		
Loblolly	97	94 - 99
Longleaf	112	110 - 113
Shortleaf	122	114 - 139
Slash	121	118 - 124
Specific gravity, ovendry weight/green volume		
Loblolly	0.40	0.34 - 0.45
Longleaf	0.39	0.36 - 0.41
Shortleaf	0.37	0.34 - 0.41
Slash	0.39	0.35 - 0.42
Longitudinal shrinkage (%)		
Loblolly	1.58	1.3 - 2.3
Longleaf	1.65	1.3 - 2.1
Shortleaf	1.85	1.1 - 2.8
Slash	2.31	1.9 - 2.7
Heat of combustion[1] (Btu per ovendry pound)	9,030	8,935 - 9,105
Extractive content[1] (%)	28.8	28.5 - 29.2
Total ash, loblolly (%)	3.46	3.34 - 3.59

[1]Mixed sample composed of equal weights from each of the four species.

broken ends and to the stomata which remain open. The waxy coating restricts penetration or transfer through other areas.

Because of their small dimensions, the mesophyll cells are not likely to prove of value in fiber applications, but the tough outer layers and fibrous central core may hold promise for such uses. The fibrous outer layers have strong cohesion, and individual fibers are difficult to separate chemically or mechanically. In the past, this tendency was of value in the production of long textile strands. The structure suggests that needles might be an auxiliary fiber source if economic conditions permit.

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