Industrial Crops & Products 109 (2017) 45–52

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

Fiber properties of axis and scale of eleven different coniferous cones

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ARTICLE INFO

Keywords:
Axis
Coniferous
Cone
Fiber properties
Scale

ABSTRACT

Fiber properties of eleven different coniferous cones, growing naturally in Turkey, were studied. Axis and scales of cones were analyzed separately. The slenderness, flexibility, and Runkel ratios were derived from measured fiber dimensions. Fiber length and fiber width of cones were between 0.93 mm and 1.87 mm, 16.6 µm and 32.2 µm, respectively. The longest fiber length was determined with 1.87 mm in *Pinus pinea* cone axis fibers. Also, the widest fiber (32.2 µm) and the widest lumen (20.0 µm) were found in *Abies equi-trojani* cone scale fibers. The thickest cell wall (8.40 µm) were found in *Pinus sylvestris* cone axis fibers. The sclerenchyma fibers, which were shorter and wider than fibers, were observed both in scale and axis of all cones. In general, cone axis fibers had lower slenderness and Runkel ratios and higher flexibility ratio than those of cone scale fibers. These results indicated that fiber properties of coniferous cones showed similarities with fibers of hardwood and nonwood species.

1. Introduction

Cones are the reproductive organs of coniferous species. They are decomposed in the soil by the time. They consist of an axis and scales around them to protect the seeds during the development. Although great amounts of cones are produced every year throughout the world, this renewable resource has found a limited usage. Recently, fiber morphology and papermaking potential of European black pine cones was evaluated by Gulsoy and Ozturk (2015). Cones of stone pine were evaluated for their potential use in particleboard and medium density fiberboard (MDF) by Buyuksari et al. (2010) and Ayrilmis et al. (2009). Also, some studies on the chemical compositions of different species cones have been revealed by several researchers (Dönmez et al., 2012; Eberhardt and Young, 1996; Ganenko et al., 2006; Garcia et al., 2017; Gonultas and Ucar, 2013; Gulsoy and Ozturk, 2015; Hafizoğlu and Reunanen, 1994; Kilic et al., 2010a, 2010b; Kilic et al., 2011; Lis et al., 2017; Macchioni et al., 2003; Micales et al., 1994; Norin and Winell, 1971; Ohtsu et al., 2000; Tümen et al., 2010; Ucar and Ucar, 2008; Yang et al., 2005, 2010). However, there is no published report on fiber morphology of cone axis and cone scale. From this point of view, the aim of this study was to determine fiber properties of cone axis and cone scale of eleven different coniferous growing naturally in Turkey.

2. Materials and method

The cones of eleven species from *Pinaceae* family (*Abies equi-trojani*, *Abies bornmulleriana*, *Abies cilicica*, *Abies nordmanniana*, *Pinus pinea*, *Pinus halepensis*, *Pinus nigra*, *Pinus brutia* Ten., *Pinus sylvestris*, *Cedrus libani*, and *Picea orientalis*) were collected from their natural growing areas (Table 1). Cones were collected from the trees when they were matured except *Pinus nigra*, *Pinus sylvestris* and *Picea orientalis.* These species were picked up from the ground at maturation time and rinsed with distilled water before splitting. Ten cones were selected from each species for fiber morphology analysis. The cones were divided two part as cone axis and cone scale for each species.

The chlorite method (Wise and Karl, 1962) was used in the maceration of cone axis and cone scale samples of each species. After maceration, fiber length, fiber width, lumen width, and cell wall thickness of 50 randomly selected fibers were measured. During measurement, two types of fibers were observed. First type was quite similar to fibers of wood which has long, thin and a regular shape and second type was sclerenchyma fibers that has shorter and thicker than first type of fibers, and also they had generally an irregular shape. The slenderness ratio (fiber length/fiber width), flexibility ratio [(lumen width/fiber width) × 100], and Runkel ratio [(2 × cell wall thickness)/lumen width] were calculated using the measured fiber dimensions. These derived values were not calculated for sclerenchyma fibers.

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http://dx.doi.org/10.1016/j.indcrop.2017.07.044
Received 17 March 2017; Received in revised form 28 July 2017; Accepted 29 July 2017

Table 1
Sampling area of cones.

Species	Sampling area
Abies cilicica	Adana, south Turkey
Abies bornmulleriana	Bartin, north west Turkey
Abies equi-trojani	Edremit, west Turkey
Abies nordmanniana	Trabzon, north east Turkey
Pinus halepensis	Gokova, Mugla, west Turkey
Pinus pinea	Bartin, north west Turkey
Pinus nigra	Bartin, north west Turkey
Pinus sylvestris	Bartin, north west Turkey
Pinus brutia	Izmir, west Turkey
Cedrus libani	Adana, south Turkey
Picea orientalis	Trabzon, north east Turkey

All data were performed using SPSS software. The data related to fiber morphology of the axis and scale of each cone was analyzed statistically using the independent *t*-test ($p < 0.05$). The same letters on columns related to fiber properties of a cone species in figures denotes that there were no statistically significant differences between the groups.

3. Results and discussion

One of the important factors in evaluation of suitability for pulp production of a raw material is its fiber properties. The fiber properties directly affect the runnability on paper machine, strength and optical properties of sheet, response to refining, and fiber-water interactions such as swelling and water retention of fibers. Long fibers are predisposed to form a porous and less uniform paper structure, coarse paper surface. Also, sheets of long fibers have higher strength properties than sheets of short fibers. On the other hand, fiber flexibility depends on lumen width and cell wall thickness of fibers. Thick-walled fibers have a negative effect on the folding endurance, burst and tensile index of paper, and a positive effect on tear index. Also, the paper obtained from thick walled fibers will be bulky, with a coarse surface, and will contain a large amount of void volume. However, thin-walled fibers provide uniform and denser paper structure.

In the cones of eleven tree species, the sclerenchyma fibers along with fibers were observed both in the axis and scale of cone (Fig. 1). Scale samples had more sclerenchyma fibers than axis. Sclerenchyma fibers with simple pith were shorter, wider, thicker-walled, and quite wider lumen than fibers which are similar to wood fibers. Sclerenchyma fibers, which are a specific cell types, have very thick lignified cell walls (Julian, 2000). Therefore, sclerenchyma fibers are very stiff and they contribute the hardness to cones. Sclerenchyma fibers also observed in leaves of monocotyledons (grasses and lilies), New Zealand flax and esparto (Julian, 2000), hemp (Blake et al., 2008), Grevillea and some woody species (Williams et al., 1984).

3.1. Fiber length

Fiber length of cone axis and cone scale of species used in this study is presented in Fig. 2 and Table 2. The length of sclerenchyma fibers both the in axis and scale were given in Table 3. The fiber length of scale fibers of fir species, *Pinus halepensis*, *Pinus nigra*, and *Pinus brutia* was longer than those of axis fibers. The longest and shortest fiber length were determined as 1.87 ± 0.06 mm and 0.93 ± 0.03 mm in *Pinus pinea* cone axis fiber and *Abies cilicica* cone axis fiber, respectively. Fiber length of axis and scale was similar to nonwoods such as tobacco (Shakhes et al., 2011), kenaf (Ververis et al., 2004) sugarcane bagasse (Hemmasi et al., 2011), cotton stalks (Ververis et al., 2004), sunflower stalks (Omotoso and Owolabi, 2015), and rice straw (Kiaei, 2014), and hardwoods such as European aspen (Gulsoy and Tufek, 2013), river red gum (Dutt and Tyagi, 2011) and Turkish white oak (Gulsoy et al., 2005) (Table 4). Fiber length differences between axis fibers and scale fibers were statistically significant except of *Pinus halepensis*, *Pinus nigra*, and *Pinus sylvestris* cone samples ($p < 0.05$) (Table 2). On the other hand, fiber length of whole cone (without splitting to axis and scale) of *Pinus nigra* was determined as 1.25 mm by Gulsoy and Ozturk (2015).

In the cone samples of all species, sclerenchyma fiber were shorter than fibers. However, in different parts of cone (axis and scale) sclerenchyma fibers were longer in the scale part (Table 3). The longest and shortest sclerenchyma fibers were observed in *Abies equi-trojani* and *Pinus nigra* by 1.27 ± 0.05 mm and 0.29 ± 0.01 mm, respectively. The differences in sclerenchyma fiber length between axis and scale were statistically significant except of *Pinus pinea* cone sample ($p < 0.05$) (Table 3). The fiber length of sclerenchyma fibers was similar to cotton stalks (Ververis et al., 2004) and river red gum (Dutt and Tyagi, 2011) (Table 4).

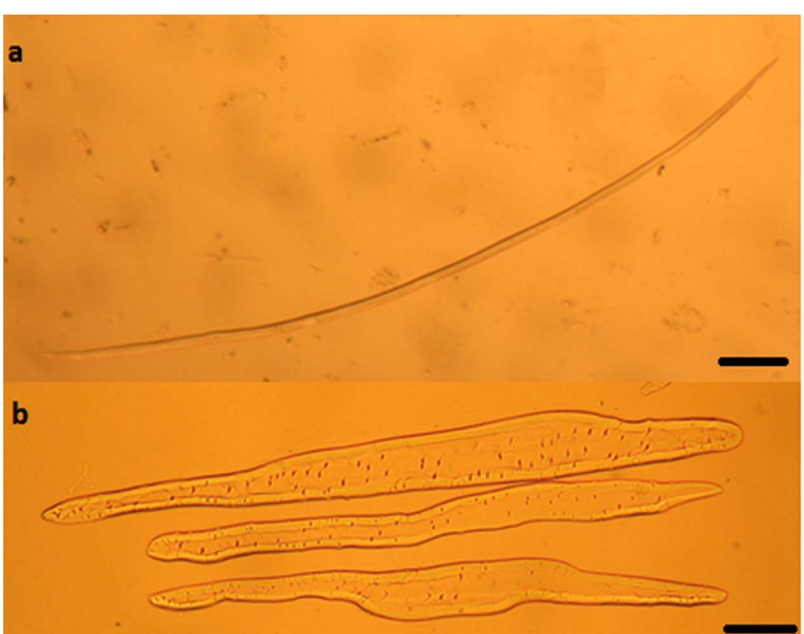

Fig. 1. The fiber (a) and sclerenchyma fibers (b) of cone scale of *Pinus brutia* (Scale bars: 75 μm).