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Anatomical structural differences between branch and trunk in *Ailanthus altissima* wood

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Abstract

Wood fiber dimensions such as length, diameter, lumen width, cell wall thickness, Runkel ratio, slenderness ratio, flexibility ratio of *Ailanthus altissima* were investigated from wood of trunk and branches. In trunk wood, the length, diameter, lumen width, cell wall thickness, Runkel ratio, slenderness ratio, flexibility ratio were 940±167, 22.8±4.63, 16.16±4.69, 3.34±1.18, 0.46±0.21, 42.97±11.57, 70.12±9.97 µm respectively, whereas for branch wood the corresponding values were 594±134, 17.81±3.53, 12.78±3.71, 2.49±0.6, 0.38±0.26, 35.31±11.03, 70.70±9.81 µm respectively. Fiber dimensions of *A. altissima* are in the normal range for hardwoods. The morphology of fibers and its fiber indices from the *A. altissima* wood is reasonably good for the purpose of paper manufacturing. The short length and thin walled fibers may be expected to give relatively dense papers which are weak in tearing strength, but are superior in burst and tensile properties.

Keywords: *Ailanthus altissima,* Wood anatomy, Runkel ratio.

Introduction

The global demand for fibrous materials in the wood-based industry has been growing, but the production of industrial wood from natural forests continues to decline. The decline in forest resources in developing countries is due to the depletion of the resources, and in developed countries due to the withdrawal of forest areas from industrial production for other uses such as recreational areas (Ashori, 2006a). Also, there is a significant pressure on standing forest resources as a result of higher demand for wood in forest industry due to the increasing population and new application areas. In order to meet the future demand and to overcome the wood shortage, studies have been conducted to utilize new or alternative resources in the forest industries as raw material components for pulp and paper production in several countries (Ashori, 2006b; Copur *et al.,* 2007).

Early research on the effect of fiber properties on paper strength (Dadswell & Wardrop, 1954; Arlov, 1959; Barefoot *et al.,* 1964) led to the general belief that paper with desirable strength properties could only be made from long-fibered wood species, softwood pulps. Subsequent studies have shown that fiber length possibly is not the overriding factor in producing paper with acceptable strength (Annergren *et al.,* 1963; Alexander & Marton, 1968; Horn, 1974).

Wood-fiber characteristics that have often been associated with paper strength-in particular, paper made from hardwoods-are the length to diameter ratio (L/D), and Runkel ratio-twice the cell wail thickness/lumen diameter (2w/l). Both are fiber parameter which, by the very nature of their required measurements, should be associated with wood fiber and not with pulp fiber. The L/D ratio has been shown to be unreliable in providing basic information on strength properties dependent upon fiber bonding (Watson & Dadswell, 1964).

The Runkel ratio is a microscopic extension of the wood density in that wail thickness and lumen width are the basic factors used in their determination. Therefore, it should not be expected to provide much more basic information than the measured wood density. It is important to reflect on this in that differences in performance of fiber-based products are traced to the pulp fiber. Consequently, performance can only be assessed by measuring morphological parameters of the pulp fiber because existing data clearly demonstrate that wood fiber undergoes internal dimensional changes under conditions of kraft pulping (Stockman, 1971a; b) The aim of this study anatomical structure differences between branch and trunk in *Ailanthus Altissima* wood were investigated.

Materials and Methods

Raw material

In this research, 3 normal *Ailanthus altissima* trees were randomly selected from in the garden of Karaj. As from each of trees; two discs were taken at breast height and branches. The test samples from the skin (mature wood) were prepared.

Measurement of fiber biometry characteristics

The pieces of *A. altissima* were defibrated using the technique developed by Franklin (1954) and then the fiber length, fiber diameter, and lumen width were measured with a microscope equipped with a Leica Image Analysis System (Quantimeta 100+). The fiber wall thickness was calculated as a difference of fiber diameter and lumen width divided in half. For dimensions of 30 fibers were randomly measured. From these data, the average fiber dimensions were calculated and then the following derived indexes were determined:

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Runkel ratio = 2 × (Wall thickness/Lumen width) (1)
Flexibility ratio= (Lumen width of fiber/Diameter of fiber) × 100 (2)
Slenderness ratio= (Length of fiber/Diameter of fiber) (3)

Results and discussion

Fiber dimensions and derived indexes

One most important parameters which determine suitability of wood as raw material for pulp and paper industry is its fiber characteristics (Kayama, 1979). The purpose of this part of the study was to provide basic information on the morphological characteristics of *Ailanthus altissima*. Lignocellulosic materials contain fiber length, fiber diameter, lumen width, and cell wall thickness. The observations made in this investigation and the results of statistical analysis indicated that there are differences in the morphological characteristics of *A. altissima* fibers. The descriptive statistics for morphological characteristics of branch and trunk in *A. altissima* wood are shown in Table 1.

Table 1. Fiber dimensions and biometrical coefficient of Ailanthus altissima

Fiber dimensions	Wood	
	Trunk	Branch
Length (µm)	940±167 (543-1355)	594±134 (309-800)
Diameter (µm)	22.8±4.63 (15.56-34.16)	17.81±3.53 (11.87-24.11)
Lumen width (µm)	16.16±4.69 (8.5-26.45)	12.78±3.71 (5.35-20.08)
Cell wall thickness (µm)	3.34±1.18 (1.41-6.06)	2.49±0.6(1.31-3.75)
Runkel ratio	0.46±0.21(0.11-1)	0.38±0.26 (0.13-0.60)
Slenderness ratio	42.97±11.57 (24.46-70.53)	35.31±11.03 (16.37-62.55)
Flexibility ratio (%)	70.12±9.97 (50.02-90.21)	70.70±9.81 (41.79-80.45)

Mean ± standard deviation (Min-Max)

The average fiber length in the trunk wood was 934 µm while in branch wood 601 µm. The shape of the fibers is similar to the structure of a honeycomb and the average length (934 µm) is like the one of hardwoods. Short fibers tend to give a dense and uniform sheet structure. This value is similar to paulownia (1002 µm), aspen (960 µm) (Law & Jiang, 2001) fiber, and is lower than hornbeam (1250 µm) fiber (Talaeipour *et al*., 2010) and is higher than wheat straw (740 µm) (Deniz *et al.,* 2004) and cotton stalks (830 µm) (Ververis *et al.,* 2004) fibers.

Fiber diameter in trunk wood was 22.6 µm while in branch 17.77 µm. Fiber diameter in trunk wood is similar to canola stalks (23.02 µm) (Enayati *et al.,* 2009) fiber, and is lower than paulownia (35.44 µm), coniferous (32-43 µm) (As *et al.,* 2002) hornbeam (23.97 µm) and cotton stalks (24.98 µm) fiber, and is higher than wheat straw (13.2 µm), rice straw (14.8 µm) (Tutus *et al.,* 2004) and *Robinia pseudoacacia* (21.15 µm) (Khattak & ghazi, 2001) fibers.

Lumen width in trunk wood was 16.02 µm while in branch wood 12.78 µm. Lumen width in trunk wood is similar to cotton stalks (16.75 µm) fiber, and is lower than coniferous (30 µm) and paulownia (26.49 µm) fiber, and is higher than hornbeam (10.69 µm), wheat straw (4.02 µm), rice straw (6.4 µm) fibers.

Cell wall thickness in trunk wood was 3.29 µm while in branch 2.49 µm. Cell wall thickness in trunk wood is similar to cotton stalks (3.4 µm) fiber, and is lower than coniferous (13-17 µm), paulownia (6.47 µm), hornbeam (6.64 µm) and Canola stalks (5.26 µm), and is higher than aspen (1.93 µm) fibers. More cell wall thickness of fibers causes more flexibility of fibers in pulp refining process. Increase of cell wall thickness has a direct effect on strength properties of fibers. Therefore it is expected that with the resulting paper strength, properties can be met after refining.

The calculated Runkel ratio for *Ailanthus altissima* fibers (0.46) is higher than that of aspen (0.23) and paulownia (0.34) fiber, and lower than was date palm rachis (0.8), cotton stalks (0.84) and hornbeam (1.24) fibers. The slenderness ratio of *A. altissima* is 42.97 and similar to that of cotton stalks (42.35), and aspen (46.15) fibers. This value is lower than hornbeam (52.14) and higher than paulownia 29.32 fibers. Generally, the acceptable value for slenderness ratio of papermaking is more than 33, respectively (Xu *et al.,* 2006).

But the flexibility coefficient of *Ailanthus altissima* fibers is similar both cotton stalks (65.31) and aspen (81.44), paulownia (75) and higher than hornbeam (44.59). According to flexibility ratio there are 4 groups of fibers (Bektas *et al.,* 1999): 1) High elastic fibers having elasticity coefficient greater than 75. 2) Elastic fibers having elasticity ratio between 50 -75: 3) Rigid fibers having elasticity ratio between 30 -50: 4) highly rigid fibers having elasticity ratio less than 30. According to this classification, the flexibility coefficient of *A. altissima* fibers is 70.12, so it is included in the elastic fibers group.

Conclusion

Fiber dimensions of *Ailanthus altissima* are in the normal range for hardwoods. The morphology of fibers and its fiber indices from the *A. altissima* wood is reasonably good for the purpose of paper manufacturing. The short length and thin walled fibers may be expected to give relatively dense papers which are weak in tearing strength, but are superior in burst and tensile properties.

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