

Physico-chemical and mechanical characterisation of the bark of selected *Ficus* species growing in Uganda

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Abstract In this study, the physical, chemical and mechanical properties of three *Ficus* species growing in Uganda were determined. Basic density and water absorption rate were (0.33 g/cm³, 134) in *Ficus natalensis*, (0.32 g/cm³, 137) in *Ficus thonningii* and (0.28 g/cm³, 145) in *Ficus glumosa*, respectively. Lignin content and tensile strength were highest in the bark of *F. natalensis*, and lowest in *F. glumosa* while cellulose content was highest in the bark of *F. glumosa* and lowest in *F. natalensis*. Based on the results, the bark is not suitable for use in industries such as paper manufacturing, where lignin is undesirable, but it can be used in manufacture of dyes and adhesives.

1 Introduction

The bark, a Non Timber Forest Product (NTFP), is the outer most covering of tree stems. NTFPs in Uganda contribute 17 % of the forest sector's contribution to gross domestic product (Cottray et al. 2006). It is widely assumed that NTFPs link conservation and rural development. Therefore, increasing economic returns of NTFPs are expected to lead to internalization of forest resource values, an incentive for conservation through local resource management (Cottray et al. 2006). *Ficus* species such as *Ficus natalensis* Hochst., *Ficus glumosa* Var. and *Ficus*

thonningii Blume., have been used for production of cloth in Uganda for a long time. Buamscha et al. (2007) noted that the use of the bark is greatly influenced by its properties. Properties of a material contribute greatly to its utilization; optimum utilization of the bark hence requires appreciating its complexity and its extreme variations in relation to chemical and physical properties (Harkin and Rowe 1971). Cognizant of this fact, this study aimed at determining the physical, mechanical, and tensile properties of the bark of selected *Ficus* trees in Uganda and in particular density, water absorption rate, lignin content, cellulose content and tensile strength, as these influence the quality of the final product made from the bark. The specific objectives were to determine the:

1. Physical properties, i.e., density and water absorption rate;
2. Chemical properties, i.e., cellulose and lignin content;
3. Tensile properties of the bark of *Ficus* species.

2 Materials and methods

Fifteen trees >10 cm diameter were debarked and bark samples of 1 m in fiber direction and 5 cm across fiber direction, without visible defects were taken at 1.3 m above the ground and labelled K1, K2 and K3 for *Ficus natalensis*, *Ficus thonningii* and *Ficus glumosa*, respectively. From each bark sample, the outer bark was scrapped off using a knife and then transported to Uganda Industrial Research Institute laboratory for testing. For the chemical tests the bark was ground evenly and sieved using a wire mesh of 350 microns. Density and water absorption rate were determined using standard methods. The chemical

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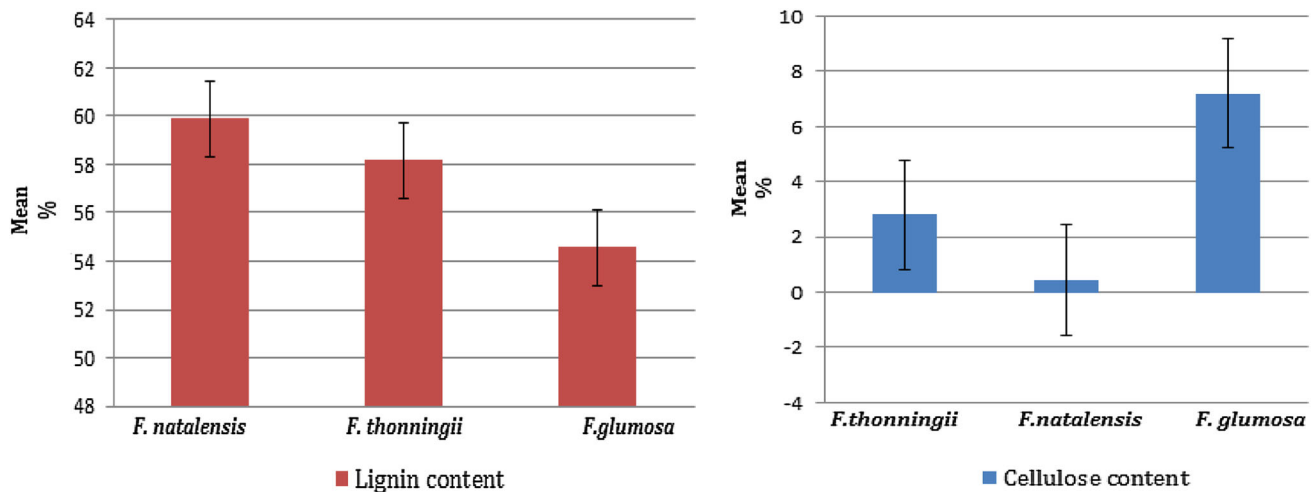


Fig. 1 Proximate chemical composition (*left = lignin, right = cellulose*) of bark of the three selected *Ficus* species

composition of the bark in terms of cellulose and lignin was determined using standard test methods, that is analytical biochemistry method and Klason lignin according to TAPPI T 222OM-02 and TAPPI UM 250, respectively. The longitudinal tensile strength of the bark samples was tested following ASTM D5035 using the Instron universal testing machine with a load cell of 25 kN. One way-analysis of variance (ANOVA) general linear model was used to determine the variation in tested properties among the three *Ficus* species. For all the tests post hoc testing using Tukey's Honest Significant Difference (HSD) test was done after ANOVA to avoid errors of omission. The test was used to conduct pair-wise comparisons for species combinations to reveal where exactly differences in bark properties exist. All statistical hypothesis tests were done at 5 % level of significance using Minitab programme, version 13.

3 Results

The mean density of the bark was 0.33 g/cm^3 (0.02) in *F. natalensis*, 0.32 g/cm^3 (0.01) in *F. thonningii* and 0.28 g/cm^3 (0.10) in *F. glumosa* with figures in brackets as standard deviations. The differences in density were not statistically significant ($F_{2, 27} = 0.83$, $P \leq 0.446$). The mean water absorption rate of the bark was 145 in *F. glumosa*, 137 in *F. thonningii* and 134 in *F. natalensis*. The differences in water absorption rate were significantly different ($F_{2, 87} = 7.88$, $P \leq 0.001$) for the three *Ficus* species. However, the post hoc test showed non-significant ($T = 0.036$, $P \leq 0.9993$) differences in water absorption rate of the bark of *F. glumosa* and that of *F. natalensis*.

The mean values of lignin content for ten samples of each species were 59, 58 and 54 % in the bark of *F.*

natalensis, *F. thonningii* and *F. glumosa*, respectively. The mean cellulose content for ten samples of each species was 7.2 % in the bark of *F. glumosa*, 2.4 % in *F. thonningii* and 0.4 % in *F. natalensis*. Cellulose content differed significantly ($P < 0.05$) in the bark of the three species, but there were no significant differences ($P > 0.05$) in lignin content of the bark of the three species (Fig. 1).

The mean tensile strength of the bark of the three *Ficus* species was 64.3, 65.3 and 52.2 N/mm^2 for *F. thonningii*, *F. natalensis* and *F. glumosa*, respectively. The tensile strength was significantly different ($F_{2, 87} = 4.50$, $P \leq 0.014$) for the bark of the three *Ficus* species. However, the post hoc test showed that differences in tensile strength between the bark of *F. natalensis* and that of *F. thonningii* ($T = -0.2062$, $P \leq 0.9768$) were statistically not significant.

4 Discussion

The differences in water absorption rate of the bark of the three species could be due to species specific physiology and chemistry which includes density, amount of cellulose, hemicellulose and presence of resins. The amount of hydroxyl groups ($-\text{OH}$) in a particular species also influences moisture resistance of the species (Dhakal et al. 2007). The differences in cellulose content of the bark of all three species studied corroborate other findings (Harkin and Rowi 1971) that vast differences in the nature and amounts of various chemical components, such as cellulose, contained within the bark can be found between different species, within a single species, depending on the age and growth site of the trees sampled and the fraction of bark examined. The lignin content in the bark of hardwoods ranges from 40–50 % according to (Harkin and

Rowi 1971), while that recorded in this study was higher. This is indicative of the high potential of *Ficus* bark for various applications such as production of dyes and paints. The high lignin content would also imply that *Ficus* bark is not suitable for production of pulp for paper due to the high costs of delignification. Lignin is an undesirable polymer and its removal during pulping requires high amounts of energy and chemicals. Differences in bark tensile strength can be attributed to the genetic makeup of the different species. In a study on the effect of blending lignin with polyethylene on physical properties, Alexy et al. (2000) found that lignin influenced the tensile strength. The high bark tensile strength in this study can be attributed to the high lignin content. The high tensile strength of the bark of *F. natalensis* implies that products and or materials from its bark will have high resistance to tear (Bauer and Speck 2012). The very low bark cellulose content for the three species (<10 %) in comparison with that (32–45 %) reported by Harkin (1969) can be explained by effects of site and associated tree growth rate.

5 Conclusion

Lignin content was exceptionally higher than that of other hardwoods, thus the bark of *Ficus* species is not suitable for use in industries such as paper manufacturing where lignin is undesirable. The bark can probably be used where high lignin content is desirable, for instance in the following industries dyes, adhesives, road binder/dust control, resins, wallboard and fertilizers.

Studies should investigate bark properties such as fibre length, extractive content, dimensional stability and

thermal conductivity to trigger other uses of the bark, thus enabling maximum exploitation of the potential of the bark.

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