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# Coparative Study on Tension and Opposite Woods of Some Species Grown under Saudia Arabia Condition

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**Abstract:** Chemical composition of four species grown at Dirab farm in Saudi Arabia was investigated. The differences among species in chemical composition were highly significant. Results exhibited that *Acacia salicina* had the highest cellulose content whereas, *Albizzia lebbeck* had more hemicellulose and *Tamarix aphylla* had the highest lignin, while *Pithecellobium dulce* had the lowest lignin content. The variation of cellulose, hemicellulose, lignin and ash content between tension and opposite woods was highly significant. In general, tension wood had less extractive content of all species under study, so tension wood can be used in pulp and paper production since the small amount of extractive contents results in increasing the pulp yield and decreasing the chemicals used in pulping and bleaching processes. Tension wood had higher average values of cellulose content of all species than normal wood. Such increment in cellulose content may be attributed to the gelatinous layer in wood fibers which is less or not lignified and largely consists of cellulose. It is evident that wood nature influenced the chemical composition of hardwood trees under study. This is very important to chemical technologists and different approaches of hardwoods. Practically, tension wood had more cellulose content and less lignin percentage. This trend can be used to obtain a high pulp yield from wood.

**Key words:** Chemical composition · Tension wood · Normal wood · Cellulose content

## INTRODUCTION

The chemical composition of wood determines the utilization of wood, varying widely between and within species and within tree in the same species, because wood is not a uniform substance. Thus trees with high cellulose content and low lignin content are usually preferred for pulp and paper making. Trees rich in extractive materials could have a higher potential for production of certain chemicals such as tannins, resins and rubber [1]. Wood cell wall is composed of three groups of substances cellulose, hemicellulose and lignin. Cellulose as the frame work substance, contributes its high tensile strength to the complex of wood structure. The presence of hemicelluloses in the cell wall has a tremendous influence on certain physical properties of wood. The function of lignin is to provide rigidity and stiffness to cell walls [1]. In addition to the three major chemical components (cellulose, hemicellulose and lignin), wood also contains quantities of extraneous components, which influence in the wood characteristics, such as sorption, shrinkage, adhesion, wettability, specific gravity, compressive and bending strength [2-10]. Ash is another secondary wood component and is considered as an undesirable material in most industrial situations. The increase of wood utilization as a fuel may causes an ash disposal problem because it will accumulate in furnaces, this problem may be eliminated since ash is useful as a soil conditioner and fertilizer when supplemented with nitrogen to produce the compost from wood wastes as a peat moss like substance [11-15].

Tension wood is commonly found in branches and leaning trunks, the trees growing on slopes or as a result of exposure to prevailing wind or due to various other causes under normal forest conditions such as the competition for light. It is believed that the formation of tension wood is a natural reaction of the tree to 'pull' the tree into a more normal, upright position. Thus, tension wood is formed in connection with movements of orientation in woody plants and is associated with eccentric pith. Generally, eccentric pith is nearer to the lower side, with the tension wood occurring above the

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pith. However, studies carried out on tension wood indicated that tension wood fibers, though more abundant on the upper side, occur on all sides of some logs. Some logs also indicated that tension wood may be in the form of concentric or crescent-shaped zones distributed throughout the cross-section of the stem [16, 17].

Wood chemical composition is an important technological factor that influences wood industries. Therefore, before suggesting proper utilization of tree woody biomass, it is essential to evaluate the basic technological properties of its wood. Thus, the objective of the present study is to assay the influence of reaction woods on the chemical composition of hardwood under Saudi Arabia conditions.

## MATERIALS AND METHODS

**Raw Materials:** In the present study four hardwood species were used viz., *Acacia salicina*, *Albizzia lebbeck*, *Tamarix aphylla* and *Pithecellobium dulce*, nearly in the same old (about 12 years old) grown at Agriculture Research and Experimental Station, Dirab, College of Food and Agriculture Science, King Saud University Saudi Arabia; 24°6′N, latitude; 46°5′E, longitude, 650 m altitude; temperature ranged between 10°C in winter and 37°C in summer as an average of each season and 50 mm annual rainfall. Soil site texture was sandy loam (61, 23 and 15% for sand, silt and clay, respectively). Cross sectional discs from leaning trunks were used for studying chemical composition. Bark free wood samples represent tension wood and normal wood were converted to longitudinal shavings and then air dried to about 8% moisture content. After air-drying the shavings were ground in a Willy mill to pass 40 mesh screen and retain on a 60 mesh screen.

**Extractives Content Determination:** Air dried wood meal (40-60 mesh) was extracted using Soxhlet method for four hours with two volume of benzene to one volume 95% alcohol, followed by four hours extraction with 95% ethanol and finally extracted with hot-water for four hours. The percentage of extractives was calculated based on the oven-dry weight of wood samples based on ASTM standard D1105-56 [18].

**Chemical Analyses:** Cellulose content was determined by the treatment of extractive-free wood meal with nitric acid and sodium hydroxide according to the method described by Nikitin [19], hemicellulose content was determined by sulfuric acid 2% according to Rozmarin and Simionescu [20], lignin content was determined according to ASTM, D1106-84, [18] and ash content of wood was determined according to the NREL Chemical Analysis and Testing Task Laboratory Analytical Procedure #005 [21].

**Statistical Analysis:** The analysis of variance was carried out according to factorial experiment in complete randomize design (CRD), described by Snedecor and Cochran [22]. First factor was species (*A. salicina, A. lebbeck, T. aphylla and P. dulce*) and second factor was wood nature (normal and tension woods) and the Duncan multiple test method at 95% level of probability was used to compare the differences among the means of species and wood nature as well as the interaction between them of extractives, cellulose, hemicellulose and ash content [23].

## RESULTS AND DISCUSSION

**Effect of Tree Species on Chemical Composition of Wood:** Data presented in Table 1 showed that the differences among species in extractives, cellulose, hemicellulose, lignin and ash contents were highly significant.

Data in Table 2 indicated that *A. lebbeck* and *T. aphylla* recorded the highest average value of extractives content (9.97 and 9.72 %), followed by *P. dulce* (8.41%), while *A. salicina* recorded the lowest average value (5.98%). The data showed also, that *A. salicina* recorded the highest average value of cellulose content (47.44%), followed by *P. dulce* (45.81%) with significant difference between the two species, while *T. aphylla* recorded the lowest average value (43.38%). The species exhibited significant difference in *hemicellulose*. *A. salicina* recorded the lowest average value (21.93%), followed by *T. aphylla* (22.99%), whereas *A. lebbeck* recorded the highest average value (24.78%). *T. aphylla* recorded the highest average value of lignin content (33.61%), while *P. dulce recorded* the lowest average value (30.40%). It may be concluded that *A. salicina* had the highest cellulose content, *A. lebbeck had* more hemicellulose and *T. aphylla* had the highest lignin, while *P. dulce* had the lowest lignin content. These results are in agreement with the findings of Abdel-Aal and Kayad [24] who found that, extractives, cellulose, hemicellulose, lignin and ash contents were highly significant among species under study.

**Effect of Wood Nature on Chemical Composition of Wood:** Data in Table 1 showed that the differences between wood nature (normal wood and tension wood) in extractive, cellulose, hemicellulose, lignin and ash content were highly significant.

Table 1: Analysis of variance of extractive, cellulose, hemicellulose, lignin and ash content of species and wood nature.

| S.O.V | Extractive | Cellulose | Hemicellulose | Lignin | Ash |
|---|---|---|---|---|---|
| Species | ** | ** | ** | ** | ** |
| Wood nature | ** | ** | ** | ** | ** |
| Species x wood nature | ** | ** | * | ** | ** |

** Significant at 0.01 level of confidence

* Significant at 0.05 level of confidence

Table 2: Wood chemical composition of *Acacia salicina, Albizzia lebbeck, Tamarix aphylla* and *Pithecellobium dulce* wood

| | Content of (%) | | | | |
|---|---|---|---|---|---|
| Species | Extractive | Cellulose | Hemicellulose | Lignin | Ash |
| *Acacia salicina* | 5.98[c] | 47.44[a] | 21.93[d] | 30.62[bc] | 1.08[c] |
| *Albizzia lebbeck* | 9.97[a] | 44.23[c] | 24.78[a] | 30.98[b] | 1.12[c] |
| *Tamarix aphylla* | 9.72[a] | 43.38[d] | 22.99[c] | 33.61[a] | 4.95[a] |
| *Pithecellobium dulce* | 8.41[b] | 45.81[b] | 23.78[b] | 30.40[c] | 1.42[b] |

* Each value is an average of 6 specimens.

** Means having the same letters in a column are not significantly different at 0.05 level of probability according to Duncan Multiple tests.

Table 3: Wood chemical composition of Acacia salicina, Albizzia lebbeck, Tamarix aphylla and Pithecellobium dulce wood

| | Content of (%) | | | | |
|---|---|---|---|---|---|
| Wood nature | Extractive | Cellulose | Hemicellulose | Lignin | Ash |
| Normal | 9.41[a] | 43.75[b] | 24.09[a] | 32.14[a] | 2.47[a] |
| Tension | 7.63[b] | 46.67[a] | 22.65[b] | 30.66[b] | 1.82[b] |

* Each value is an average of 12 specimens.

** Means having the different letters in a column are significantly different at 0.05 level of probability according to Duncan multiple tests.

**Effect of Wood Nature on Extractives Content:** Data in Table 3 indicated that, normal wood had higher values of extractive content (9.41%) than tension wood (7.63%). For the interaction between species and wood nature, Fig. 1 shows the effect of wood nature on extractive content for *A. salicina*, *A. lebbeck, T. aphylla* and *P. dulce.* Tension wood decreased extractive content of all species under study, so tension wood can be used in pulp and paper production since the small amount of extractive contents results in increasing the pulp yield and decreasing the chemicals used in pulping and bleaching processes. Miranda *et al.* [25] obtained in 8-year-old *Eucalyptus globulus* trees a negative correlation between extractives and pulp yield. The same behavior was observed by Gominho [26] who compared pulp yield from extractive-free wood and wood with extractives and found a tendency to decrease pulp yield with the presence of extractives. Extractives also influence pulp brightness because extractives and lignin difficult the bleaching. Although no relation was obtained between extractives and brightness, samples with lower extractives content produced brighter pulps [26]. Esteves *et al.* [27] found that, the effect of extractives content in *Pinus pinaster* on pulp yield was negative.

**Effect of Wood Nature on Cellulose Content:** Data in Table 1 showed that the differences among species, wood nature and their interactions were highly significant. Data also indicated that, tension wood had higher average values (46.67%) than normal wood (43.75%). For the interaction between species and wood nature, Fig. 2 illustrated that, the tension wood increased the cellulose content of each species and this increase of cellulose content may be due to the gelatinous layer (G-layer) in wood fibers which is less or not lignified and largely consists of cellulose. Tension wood of *A. salicina* had the highest average value (48.35%), while the lowest average value was confined to normal wood of *A. lebbeck* (41.43%). The increase in cellulose content was in agreement with those obtained by Chang and Duh [28] who found that, the tension wood contained more cellulose content than normal wood in *Acacia* spp.

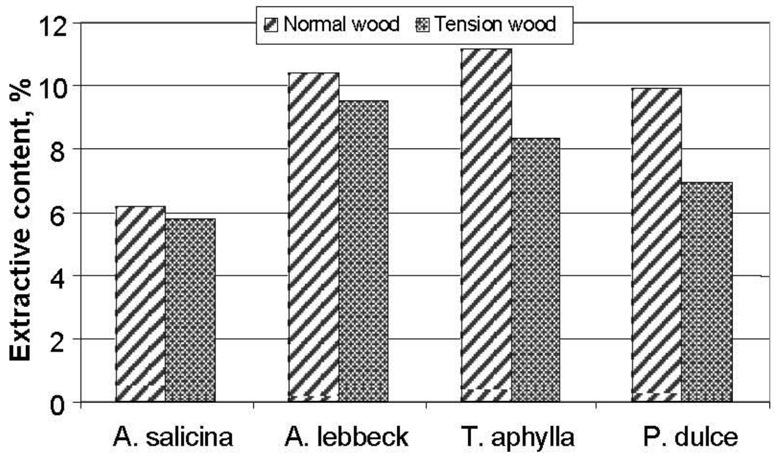


Fig. 1: The relationship between extractive content and wood nature for *A. salicina, A. lebbeck, T. aphylla* and *P. dulce.*

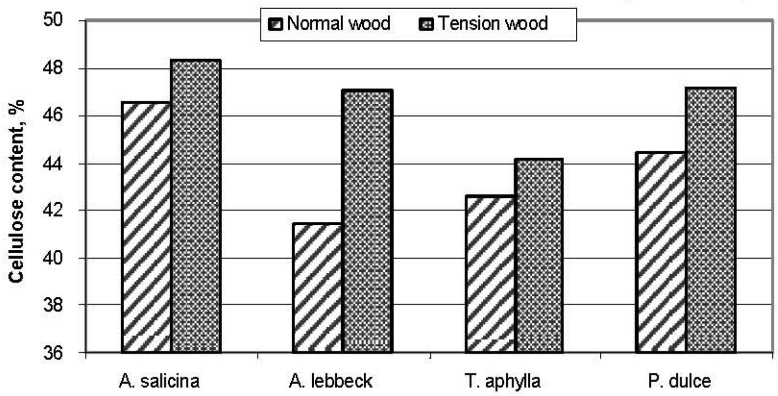


Fig. 2: The relationship between cellulose content and wood nature for *A. salicina, A. lebbeck, T. aphylla* and *P. dulce.*

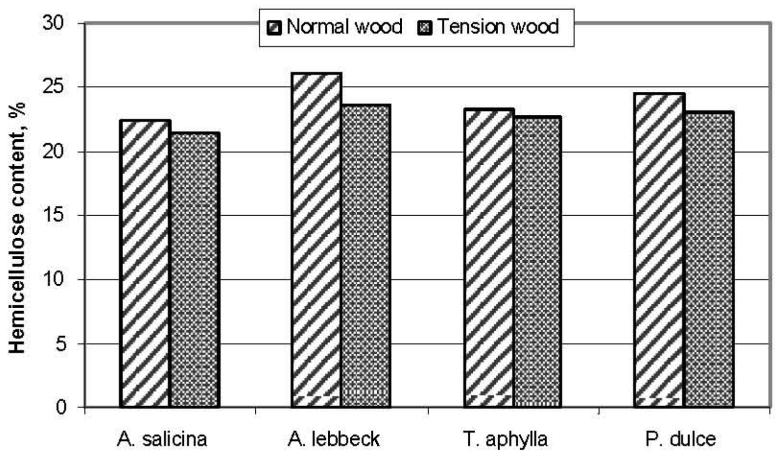


Fig. 3: The relationship between hemicellulose content and wood nature for *A. salicina, A. lebbeck, T. aphylla* and *P. dulce.*

Yashiro *et al.* [29] found that the average cellulose content in a straight section of a beech tree (*Fagus crenata*) was 56.2 % and at the crooked part of the same tree the average was 61.8 %. The gelatinous layer has been demonstrated to be more than 98 percent cellulose.

**Effect of Wood Nature on Hemicellulose Content:** Data in Table 1 showed that the differences among species and wood nature were highly significant and also the interaction in hemicellulose content was significant. Data in Table 3 indicated that tension wood had lower

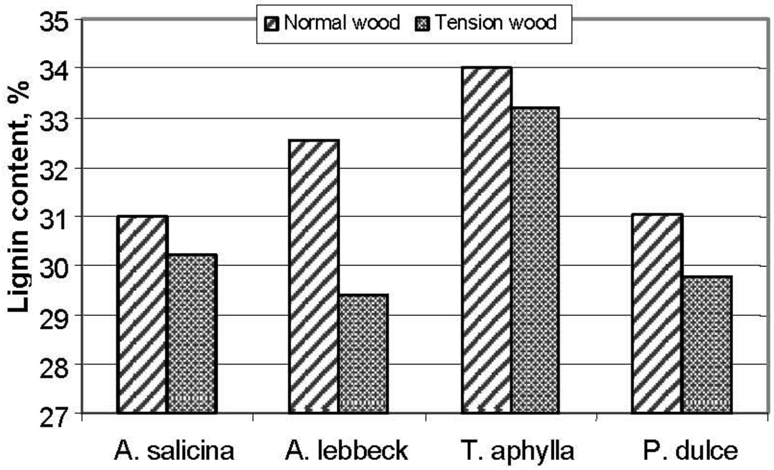


Fig. 4: The relationship between lignin content and wood nature for *A. salicina*, *A. lebbeck*, *T. aphylla* and *P. dulce*.

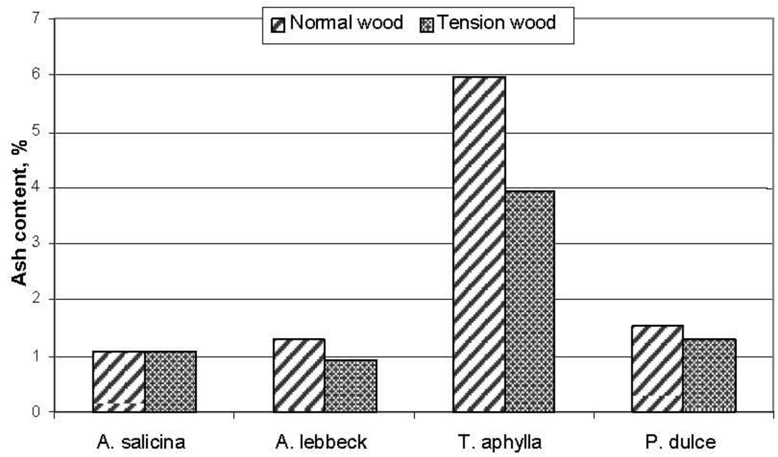


Fig. 5: The relationship between ash content and wood nature for *A. salicina*, *A. lebbeck*, *T. aphylla* and *P. dulce*.

hemicellulose content (22.65%) than normal wood (24.09%). For the interaction between species and wood nature, Fig. 3 shows the effect of wood nature on hemicellulose content for *A. salicina*, *A. lebbeck*, *T. aphylla* and *P. dulce*. Also Fig. 3 indicated that the highest average was recorded by normal wood of *A. lebbeck* (26.02%), while the lowest average was confined to tension wood of *A. salicina* (21.39). The decreased in hemicellulose content was in agreement with those obtained by Fujii *et al.* [30] who found that, tension wood contained less pentosan than other parts of wood.

**Effect of Wood Nature on Lignin Content:** Table 1 illustrates the differences among species and wood natures were highly significant. The results in Table 3 indicated that, normal wood had higher lignin content (32.14%) as compared to tension wood (30.66%). For the interaction between species and wood nature, Fig. 4 showed that tension wood had lower lignin content as compared to normal wood in four species. The averages of lignin content of tension wood were 30.25, 29.41, 33.20 and 29.79%, while the averages of lignin content of normal wood were 31.00, 32.54, 34.02 and 31.02% for *A. salicina*, *A. lebbeck*, *T. aphylla* and *P. dulce* respectively. These results are in complete agreement with those obtained by Chang and Duh [28] who found that the tension wood contained less lignin content than normal wood in *Acacia* spp. and Fujii *et al.* [30] who found that tension wood contained less lignin and more alpha-cellulose than opposite wood of Japanese beech (*Fagus crenata* Blume) and Panshin and de-Zeeuw[31] who found that, the lignin content of tension wood is lower than of normal wood and lignin is not present in the G-layers.

**Effect of Wood Nature on Ash Content:** Table 1 illustrates the differences among species and wood natures were highly significant. Data in Table 3 indicated that, normal wood had higher ash content (2.47%) as compared to tension wood (1.82%). For the interaction between species and wood nature, Fig. 5 showed that tension wood had lower ash content as compared to normal wood in four species. The averages of ash content of tension wood were 1.07, 0.93, 3.95 and 1.31%, while the averages of ash content of normal wood were 1.09, 1.30, 5.96 and 1.52% for *A. salicina*, *A. lebbeck*, *T. aphylla* and *P. dulce* respectively. This increment of ash content attributed to higher percentage of sapwood in normal wood than tension wood. These results are in disagreement with that obtained by Fujil ***et al.*** [30] who found that ash content in tension was somewhat high in Japanese beech (*Fagus cernata*).

## CONCLUSIONS

Based on the results of this study, it can be concluded that, although tension wood exhibited significantly higher values for cellulose content it had lower extractives and lignin content than normal wood, so, tension wood can be recommended for pulp and paper production or turn to ethanol. Finally, species are difference in there cellulose, hemicellulose, lignin and ash contents.

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