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Research Article

Evaluation of Paper Pulp and Paper Making Characteristics Produced from Different African Woody Trees Grown in Egypt

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Abstract

Background: There is a global need to search for new types of fibers's wood to assess its suitability for the paper production as a result of the population increase in the world. **Objective:** Therefore, this trial was conducted to evaluate paper pulp produced and determination of the papermaking characteristics from woods of *Populus alba*, *Eucalyptus camaldulensis*, *Acacia nilotica* as hardwoods and *Cupressus sempervirens* as a softwood. **Materials and Methods:** for producing fibrous raw materials which can be converted into paper. Pulp production of different wood samples, pulp yield, bleaching process and beating process were measured. In addition, physical methods (fiber length and crystallinity index) and properties (tensile index, breaking length, bursting index, tear index and brightness) of the paper sheet were determined. The data were then analyzed using using Duncan Multiple Range Test (DMRT) at 5%. **Results:** The results indicated that *Acacia nilotica* wood produced the significant superior value in net pulp yield. Also, pulp produced from *Eucalyptus camaldulensis* pronounced more changes in lignin which greatly decreased, in addition, alfa cellulose raised up to the maximum value during pulping processing followed by *Populus alba*. Chrystallinity index tended to the maximum value in *Populus alba*. In addition, bleached pulp of *Populus alba* was significantly in alfa cellulose and the maximum value in pentosan. Regarding fiber length, the results demonstrated that *Cupressus sempervirens* recorded the longest fiber length. Also, the study declared that *Populus alba* recorded the highest increases values in breaking length. In this respect papers produced from wood of *Populus alba* had the highest quality in burst index conversely. As regards tear index of papers, it is clear that paper induced from soft wood species *Cupressus sempervirens* was better and over grade than all the other species. **Conclusion:** In this regard brightness of papers manufactured from both *Populus alba* and *Eucalyptus camaldulensis* were much better in quality. Therefore, it is possible to use *Populus alba* for producing papers high quality instead of importation from the abroad.

Key words: African trees, *Populus alba*, net pulp yield, paper testing, physical methods, chemical composition

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

World paper consumption was about 300 million tons in 1996/1997 and raised above 400 million tons in the year 2010 and is expected to 500 million tons in 2015[1]. In view of the storage of conventional raw materials for pulping and the increasing demand for paper products worldwide, non-woody plants and agricultural residues attracted renewed interest. Low lignin content resulting in reducing the energy and chemicals used during pulping[2]. The composition of wood and technical properties of producing cellulose and fibers were also evaluated to indicate the traits of the produced pulp.

Paper strength depends upon lignin and cellulose content raw plant materials. Pulp mechanical strength and especially tensile are directly proportional to cellulose content[3] whereas lignin is an undesirable polymer and its removal during pulping requires a high amount of energy and chemicals.

Low lignin content of a lignocellulose material reduces the pulping time and chemical change compared to those of other nonwoody raw materials[4]. Cellulose is the abundant organic chemical, it is a white fibrous substance with great affinity for water and it is insoluble in water and neutral organic solvents. All these properties contribute to the suitability of cellulose for manufacture into papers[5]. Kraft pulps have excellent technological properties and the Kraft process is used mainly in the production of high strength pulps. The original disadvantages of the Kraft process such as bleachability of the pulps and complicated recovery of the chemicals have now largely been eliminated[6]. The pulp must be subjected to bleaching in order to remove or reduce the color creating constituents. Bleaching is the treatment of pulps with chemical reagents which should be more specific to lignin attack than those reagent used in the cooking stage to increase pulp brightness. In chemical pulps, bleaching means removal of lignin, whereas in mechanical and high yield pulps of bleaching chemicals after many of the chromophores in lignin. Bleaching mechanical pulps are often referred to as brightening[6]. The brightening of cellulose fibers requires lignin decolorization but not necessary its destruction, except with dissolving pulps were decolorized lignin interfere chemically and physically with the reactions of dissolved, filtration. Moreover, after brightening or bleaching pulp strength properties should be acceptable for the end product intended[7]. The tensile-tear relationship is one of the most important parameters for paper makers[8-10]. Meanwhile, the pulp yield and kappa number were not correlated with wood density[11]. The aim of this study was to evaluate the wood of some timber African trees grown in Egypt for producing fibrous raw materials for paper industry.

MATERIALS AND METHODS

This investigation was carried out during the season of 2013 and 2014, to evaluate the properties of paper pulping produced from wood of four different African timber tree species grown in North of African represented in Egypt, namely *Populus alba*, *Eucalyptus camaldulensis*, *Acacia nilotica* as hardwood species and *Cupressus sempervirens* as softwood.

Procedure: *Populus alba*, *Eucalyptus camaldulensis* and *Cupressus sempervirens* were obtained from the nursery of Forestry and Timber Trees Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt, while *Acacia nilotica* have taken from the Egyptian Agriculture Museum in March 2013 and 2014.

Three samples of different wood taken from the four woody trees at 11 years old were cut in the main stem at breast height and the barks were separated from the stem manually. Debarked samples were converted to chips in the average dimension of 1×10×30 mm and then oven dried.

Kraft pulping: Pulp production of different wood samples was processed due to the method of Vicentim *et al.*[12], as follows: A known weight chip was cooked in laboratory digester at 165°C. The ratio of wood chips/cooking liquor was 1:6 (w/v). The pulping liquor contained NaOH and Na_2S quantities sufficient to provide 25% of sulfide and active alkali of 26%. The heating time required to reach this temperature was 45 min and the cooking time at maximum temperature was 180 min. After the heating period, the digesters were cooled for 2 h to reach approximately 40°C. Cooked wood chips were filtered and washed with a tap water until the filtrate pH became neutral. Pulp yield was determined as follows[13]:

$$\text{Pulp yield} = \frac{\text{Dry weight pulp}}{\text{Dry weight chips}} \times 100 \quad (1)$$

Calculated change of chemical composition during precise:

$$\text{Change (\%)} = \frac{C_a - C_b}{C_b} \times 100 \quad (2)$$

Where:

C_a = Concentration of compound after precise

C_b = Concentration of compound before precise

Bleaching process: Chelation of the pulp was conducted before the bleaching process to get rid of metal ions present in the non-bleached pulp[14]. The chelation stage was performed at 80°C for 40 min at 10% consistent with 0.4% EDTA (5 g L^{-1}) followed by washing prior to bleaching, then, bleached with sodium hypochlorite 4% wt. (based on pulp) at two stages for 1 h at 50°C.

Beating process: Bleached pulp was done at 6% consistent with diluted water in the standard disintegrator at a speed of 3000 rpm. The dewatering ability of pulp was then measured in degree Schopper-Riegler up to 40-45°SR according to National Standards ISO 5267/1 and BS 56035/1. PFI MILL.

Paper sheet making: The paper sheets were prepared according to Scan, standard method using the sheet former of AB Lorentzen and Wettre (Stockholm, Sweden). A sheet of 165 mm diameter and 214 cm^2 surface area was formed by using 1.43 g oven-dry pulp. After sheet formation, the sheet was pressed for 4 min by means of a hydraulic press at 5 kg cm^{-2} and then dried in a rotating cylinder at 65°C for 2 h. The sheets were then conditioned at 18-20°C and relative humidity of 65%.

Basis weight was the number of grams per square meter of paper[15].

$$\text{Basis weight} = \frac{\text{Weight of paper sheet (g)}}{\text{Area of the paper sheet (m}^2\text{)}} \quad (3)$$

All basic weights of hand sheet paper were 80 g for the four spices to study properties of the paper sheet.

Physical methods

Fiber length: Three samples were macerated in a mixture of glacial acetic acid and 30% hydrogen peroxide (1:1) at 60°C for approximately 48 h. After de-lignification was completed, the preparation was washed with distilled water with mild shaking then the macerated fibers were stained with acridine orange dye and their dimensions were measured. For each point, 50 randomly selected filters were measured (mm) in the wet condition to the nearest 0.01 mm by projecting fiber images onto screen according to Wilson[16].

Crystallinity index: The relationship between microfibril angle and relative degree of crystallinity and the mechanical properties of wood samples, wide angle X-ray diffraction analysis were conducted Shimadzu diffractometer (XRD-6000), with monochromatic Cu Ka radiation (k = 0.1542 nm). The size that was used for MFA testing was 1 mm thick ×15 mm long×15 mm width with 10 copies per sample. The method used for the fiber wall layers was computed with the Eq. 1 and a parameter T defined according to Cave[17]. The method of measuring the relative degree of crystallinity was as follows: the XRD pattern was recorded within an angle range of 2θ from 0 to 65° with a scanning rate of 0.05° sec^{-1}. Discs with a diameter of 13 mm and a thickness of 1.6 mm were made by compressing 0.2 g of flour. The relative degree of crystallinity (CrI %) was calculated based on the Segal method from the following Eq. 4[18], with 6-8 copies sample.

$$\text{MFA} = 0.6\,T \quad (4)$$

where, T is the X-ray diffraction parameter, MFA is the microfibril angle.

$$\text{CrI (\%)} = \frac{I_{002} - I_{am}}{I_{002}} \times 100 \quad (5)$$

where, I_{002} represents both the crystalline and amorphous and I_{am} represents only the amorphous part.

Paper sheet properties

Tensile index: The tensile index was estimated according to test methods TAPPI 220 sp-01[19]. The tensile index was expressed as N m g^{-1}.

Breaking length: The breaking length was estimated according to test methods TAPPI 220 sp-01[19]. The breaking length was expressed as km.

Bursting index: Bursting index was conducted according to TAPPI standard method 220 sp-01[19]. A Mullen tester (Perkins, Chicopee, Mass., USA) was used. The bursting index was expressed as kPam^2 g^{-1}.

Tear index: The tear resistance was measured according to TAPPI standard 220sp-01[19]. The tearing index was the average force, in grams, required to tear the sheet clamped in the tester.

$$\text{Tear index (mN m}^2\text{ g}^{-1}) = \frac{100 \times \text{Force in g to tear a single sheet}}{\text{Basis weight}} \quad (6)$$

Brightness: Brightness was determined on an Elrepho brightness meter according to Francis *et al.*[20].

Statistical analysis: The data were subjected to statistical analysis (one-way ANOVA at 5%) of variance and the means were compared using DMRT (Duncan Multiple Range Test) at 5%[21].

RESULTS AND DISCUSSION

Net pulp yield: Results presented in Table 1 obviously cleared that *Acacia nilotica* wood gave significantly the highest net pulp yield in an average value of 61.62% compared to other species, followed by *Eucalyptus camaldulensis* 57.64% whereas *Populus alba* wood produced the intermediate value of 55.15%. Meanwhile, *Cupressus sempervirens* had significantly the inferior value of pulping yield 51.07%. It means that softwood species represented by *Cupressus sempervirens* recorded the least pulp yield than hardwood species. This may be referring to increasing cellulose and Hemicelluloses and decreasing lignin in hardwood than softwood. These results were in the same line of those obtained by Vicentim *et al.*[12], who mentioned that screened pulp yield in *Eucalyptus grandis* ranged from 59-62% as well as Santos *et al.*[11] reported that in *Acacia melanoxylon* pulp yield ranged from 47.9-55.0%.

Table 1: Net pulp yield of *Cupressus sempervirens, Acacia nilotica, Populus alba* and *Eucalyptus camaldulensis*

Tree species	Yield (%)
Cupressus sempervirens	51.07±3.22^{c}
Acacia nilotica	61.62±4.07^{a}
Populus alba	55.15±2.59^{bc}
Eucalyptus camaldulensis	57.64±2.94^{ab}
L.S.D.$_{(0.05)}$	6.12

Each value represents the mean of the two seasons of three replicates; the data expressed in SD, ± it is mean that the dispersion of the data from its mean by increases or decreases of the stander deviation value, Mean values with the same letters in column are not significantly different by Duncan's Multiple Range Test at $p \leq 0.05$

Chemical composition of pulp

Lignin content: The data illustrated in Table 2 show that pulp of *Acacia nilotica* contained significantly the highest value of lignin percentages 17.56% followed by *Populus alba* 16.31%. However, there were no significant differences in between, whereas both of *Cupressus sempervirens* and *Eucalyptus camaldulensis* pulp recorded the least value of lignin 13.51 and 12.15%, respectively and the differences were not significant in between.

Alfa cellulose: Concerning alpha cellulose percentage it can be concluded from the data presented in Table 2 that alfa cellulose significantly the highest decreased in a descending order as the studied species arranged were *Populus alba*, *Eucalyptus camaldulensis*, *Acacia nilotica* and *Cupressus sempervirens* with the average values of 71.15, 70.37, 67.72 and 64.99%, respectively.

Pentosan: Regarding pentosan percentage in the pulp of the different studied species, it can be observed from the data demonstrated in Table 2 that *Populus alba* pulp contained the superior value of 13.08%, followed by *Acacia nilotica* which had 12.36% although the differences were not significant in between them. However, *Eucalyptus camaldulensis* pulp and *Cupressus sempervirens* gave the inferior same values approximately 10.96 and 10.25%. The aforementioned results illustrated that pulp of *Acacia nilotica* wood gave the highest value of lignin, while *Populus alba* pulp contained higher values of both alpha cellulose and pentosan than the other species, on the other hand, *Cupressus sempervirens* as soft wood species pulp gave the lowest values in lignin, meaning that the pulp produced from its wood was better than all the hardwood species.

Table 2: Chemical composition of pulp and change of chemical composition during pulping of *Cupressus sempervirens, Acacia nilotica, Populus alba* and *Eucalyptus camaldulensis*

	Chemical composition of pulp			Change of chemical composition during pulping		
Tree species	Lignin (%)	Alfa cellulose (%)	Pentosans (%)	Lignin (%)	Alfa cellulose (%)	Pentosans (%)
Cupressus sempervirens	13.51±0.72^{b}	64.99±1.88^{d}	10.25±0.50^{b}	-57.46±3.05^{b}	51.53±2.47^{b}	-9.29±0.29^{c}
Acacia nilotica	17.56±1.16^{a}	67.72±2.78^{c}	12.36±0.63^{a}	-43.02±3.48^{a}	49.13±2.51^{c}	39.98±2.04^{a}
Populus alba	16.31±0.60^{a}	71.15±2.63^{a}	13.08±0.51^{a}	-46.45±1.72^{a}	51.58±2.01^{b}	-10.84±0.40^{c}
Eucalyptus camaldulensis	12.15±0.64^{b}	70.37±2.18^{b}	10.96±0.35^{b}	-62.64±3.51^{b}	56.73±2.41^{a}	-4.20±0.18^{b}
L.S.D.$_{(0.05)}$	1.53	0.72	0.96	5.70	0.40	2.02

Each value represents the mean of the two seasons of three replicates; the data expressed in SD, ± it is mean that the dispersion of the data from its mean by increases or decreases of the stander deviation value, Mean values with the same letters in column are not significantly different by Duncan's Multiple Range Test at $p \leq 0.05$

Table 3: Chemical composition of bleached pulp and change of chemical composition during bleaching of *Cupressus sempervirens, Acacia nilotica, Populus alba* and *Eucalyptus camaldulensis*

	Chemical composition of bleached pulp		Change of chemical composition during bleaching	
Tree species	Alfa cellulose (%)	Pentosans (%)	Alfa cellulose (%)	Pentosans (%)
Cupressus sempervirens	74.13±3.85[c]	11.23±0.55[c]	14.06±0.77[b]	9.56±0.47[b]
Acacia nilotica	80.05±5.04[a]	11.90±0.77[b]	18.21±0.78[a]	-3.64±-0.24[c]
Populus alba	78.29±2.98[ab]	15.47±0.54[a]	10.04±0.48[c]	18.27±0.82[a]
Eucalyptus camaldulensis	75.88±4.33[b]	9.77±0.64[d]	7.83±0.45[d]	-10.86±-0.39[d]
$L.S.D._{(0.05)}$	2.44	0.18	0.31	0.99

Each value represents the mean of the two seasons of three replicates; the data expressed in SD, ± it is mean that the dispersion of the data from its mean by increases or decreases of the stander deviation value, Mean values with the same letters in column are not significantly different by Duncan's Multiple Range Test at $p \leq 0.05$

Changes in chemical composition during pulping

Changed in lignin: As shown in Table 2 there was a decrease in lignin of all studied species during pulping. *Eucalyptus camaldulensis* performed the highest decrease significantly (62.64%) in lignin during the pulping process as compared to the decreasing, which occurred in *Acacia nilotica* (43.02%) and *Populus alba* (46.45%), respectively. The differences between the decreasing in lignin of both *Eucalyptus camaldulensis* and *Cupressus sempervirens* were not significant. While, the differences in decreasing of lignin during the pulping process between *Acacia nilotica* and *Populus alba* were significant. The former results displayed that lignin suppressed during the pulping process was the most value in *Eucalyptus camaldulensis* followed by those of *Cupressus sempervirens*. In addition, Shakhes *et al.*[22] reported that the lignin content of the hardwood was higher than that of Tobacoo.

Changes of alfa cellulose: Regarding changing in alfa cellulose during pulping process the results indicated in Table 2 demonstrated that alfa cellulose was increased significantly in all studied species. *Eucalyptus camaldulensis* recorded significantly the highest increase of alfa cellulose where the amount attained to 56.73% as compared to all studied species, whereas those of *Acacia nilotica* was the least one in ranking 49.13%. On the other hand, the increases of alfa cellulose during the pulping process were the intermediate in *Cupressus sempervirens* and *Populus alba*; 51.53 and 51.58% represented similar values approximately in between them. Jonoobi *et al.*[23] demonstrated that the content of lignin and hemicellulose decreased in the pulping process and that lignin was almost completely removed during bleaching.

Changes of pentosan: Changes of pentosan during the pulping process were over in *Acacia nilotica,* where it increased 39.98% (Table 2). While, pentosan declined in the other species and the reduction was the highest 10.84% in *Populus alba*, followed by those of *Cupressus sempervirens* 9.29% whilst the decreases was the least one 4.20% in *Eucalyptus camaldulensis* in pentosan during the process. It can be concluded that changes in chemical composition were more pronounced in *Eucalyptus camaldulensis* pulp in which changing in lignin was negative. While, it was the positively in alfa cellulose that was the most one with an average values of 62.64 and 56.73%, respectively, followed by those obtained from *Cupressus sempervirens* where the changing in lignin was negative. While, in alfa cellulose it was positive as attained 57.46 and 51.53%, respectively, moreover, those changes either negatively in lignin or positively in alfa cellulose were insignificant between *Cupressus sempervirens* and *Eucalyptus camaldulensis*.

Chemical composition of bleached pulp: Data presented in Table 3 show the chemical composition of bleached pulp that soft wood represented in *Cupressus sempervirens* recorded significantly decreased in alfa cellulose percentage of bleached pulp compared with the other species in which the average value was 74.13%. On the other hand, *Acacia nilotica* wood produced the highest value 80.05% in alfa cellulose of bleached pulp, followed by those of *Populus alba* 78.29%. As regard pentosan, it is evident from Table 3 that *Populus alba* was detected the most value of pentosan in bleached pulp 15.47% meantime *Eucalyptus camaldulensis* resulted in the inferior value of 9.77% pentosans. While, both of *Cupressus sempervirens* and *Acacia nilotica* associated with the same value nearly 11.23 and 11.90%.

Changes in chemical composition during bleaching: As shown in Table 3 the results pointed out that there were significant differences among all studied species in changes of alfa cellulose percentage during bleaching pulp processing. *Acacia nilotica* revealed the most changes in alfa cellulose in average values of 18.12%, followed by *Cupressus sempervirens* 14.06%. Whereas, the lowest percentage during bleaching was due to *Eucalyptus camaldulensis*. In addition, *Populus alba* had the intermediate in changing of alfa cellulose during bleaching pulping 10.04%. In this respect, *Populus alba* changed positively in pentosan during bleaching pulp where pentosan increased to a maximum value of 18.27 also the pentosan increased 9.56% in *Cupressus sempervirens* in contrast, both of *Eucalyptus camaldulensis* and *Acacia nilotica* decreased negatively in pentosan as the values were 10.86 and 3.64%, respectively.

Fiber length: The obtained data in Table 4 showed that there were significant differences ($p \leq 0.05$) among all the studied species. A steady, diverse in their values where the fiber length in wood of *Cupressus sempervirens* was the longest one 2.04 mm in comparison among the other species. In addition, fiber length of *Populus alba* was the intermediate in raking arrangement 1.21 mm. However, the differences between *Cupressus sempervirens* and *Populus alba* were significant. On the other hand, the shortest fiber length correlated with wood of *Eucalyptus camaldulensis* 0.78 mm. While, fiber length of *Acacia nilotica* wood was 0.95 mm taller than of *Eucalyptus camaldulensis* wood. The previously obtained results coincided with those obtained by many scientists such as El-Osta and Megahed[24], who found that the average values of fiber length of the sampled trees ranged between 0.72 mm in *Parkinsonia aculeate* and 1.14 mm in *Acacia karroo*, also Geyer *et al.*[25] mentioned that the fiber length of 4 years old trees of *Populus clones* was relatively short 0.84 mm.

Table 4: Fiber length and crystallinty index of *Cupressus sempervirens*, *Acacia nilotica*, *Populus alba* and *Eucalyptus camaldulensis*

Tree species	Fiber length (mm)	Crystallinty index
Cupressus sempervirens	2.94±0.16[a]	37.49±1.84[d]
Acacia nilotica	0.95±0.04[c]	45.20±3.05[c]
Populus alba	1.21±0.06[b]	55.24±2.49[a]
Eucalyptus camaldulensis	0.78±0.04[d]	54.16±1.95[b]
$LSD_{(0.05)}$	0.09	0.96

Each value represents the mean of the two seasons of three replicates; the data expressed in SD, ± it is mean that the dispersion of the data from its mean by increases or decreases of the stander deviation value, Mean values with the same letters in column are not significantly different by Duncan's Multiple Range Test at $p \leq 0.05$

Crystallinity index: The obtained data in Table 4 revealed that soft wood species represented in *Cupressus sempervirens* species significantly decreased in the crystallinity index as compared to hardwood species in which the crystallinity index attained 37.49%. While, those of *Populus alba* significantly exceeded to maximum values as compared to all the other studied species 55.24%. In addition, the crystallinity index of *Eucalyptus camaldulensis* was the second one in ranking 54.16%. Meantime, *Acacia nilotica* was in the third one of arrangement 45.20%, while that of *Cupressus sempervirens* was the last one 37.49%. From the aforementioned results, it might be observed that crystallinity of *Cupressus sempervirens* as softwood was the least one compared to crystallinity index in hardwood of species. These results were in accordance with those reported by Poletto *et al.*[26], who found that crystallinity index was 34.4% in *Eucalyptus grandis*.

Paper testing

Breaking length: As shown in Table 5 the results indicated that *Acacia nilotica* and *Populus alba* paper sheet gave significantly the best values in breaking length where they were 4.75 and 4.78 km, respectively. However, the differences were not significant in between sequentially the papers produced from wood of both of them were preferable in the paper industry. Followed by those of *Cupressus sempervirens* as the value of breaking length was 4.41 km. While, paper manufactured from wood of *Eucalyptus camaldulensis* was the least in breaking length 3.16 km than all the other used species. So the better paper industry from the wood of *Populus alba*.

Burst index: It can be noticed from data presented in Table 5 that wood of *Populus alba* was more suitable in burst index than the other species in which the values of burst index recorded the highest value of 2.93 (kPa cm^2 g^{-1}). Followed by those induced from both of *Cupressus sempervirens* and *Acacia nilotica* as the values were 1.66 and 1.62 kPa cm^2 g^{-1}, respectively. On the other hand, burst index in papers

Table 5: Paper testing of *Cupressus sempervirens, Acacia nilotica , Populus* and *Eucalyptus camaldulensis*

Tree species	Breaking length (km)	Burst index (kPa cm^2 g^{-1})	Tear index (mN cm^2 g^{-1})	Brightness (%)
Cupressus sempervirens	4.41 ± 0.19[b]	1.66 ± 0.06[b]	4.68 ± 0.23[a]	73.6 ± 1.55[b]
Acacia nilotica	4.75 ± 0.22[a]	1.62 ± 0.07[b]	1.94 ± 0.08[d]	73.7 ± 3.76[b]
Populus alba	4.78 ± 0.18[a]	2.93 ± 0.11[a]	3.72 ± 0.11[b]	79.4 ± 2.70[a]
Eucalyptus camaldulensis	3.16 ± 0.13[c]	1.18 ±0.05[c]	2.15 ± 0.09[c]	79.0 ± 3.24[a]
$L.S.D._{(0.05)}$	0.055	0.055	0.123	1.638

Each value represents the mean of the two seasons of three replicates; the data expressed in SD, ± it is mean that the dispersion of the data from its mean by increases or decreases of the stander deviation value, Mean values with the same letters in column are not significantly different by Duncan's Multiple Range Test at $p \leq 0.05$

industrialized from the wood of *Eucalyptus camaldulensis* was the least one in its quality where it recorded 1.18 kPa cm^2 g^{-1}. It means that *Populus alba* deduced the better paper in its burst index than the other species. Meanwhile, Dutt and Tyagi[27] found that there is an insignificant decrease in burst index of different Eucalyptus species.

Tear index: As for tear index it can be observed from results pronounced in Table 5 that *Cupressus sempervirens* as soft wood gave the best traits in the tear index of its papers more than those produced from hardwood species in which significantly the highest value was 4.68 mN cm^2 g^{-1}. The papers in manufactured from wood of *Populus alba* were better than the other hardwood species where the value was 3.72 mN cm^2 g^{-1}. Meanwhile, tear index of papers industrialized from *Eucalyptus camaldulensis* wood came in the second grade 2.15 mN cm^2 g^{-1}. In addition, *Acacia nilotica* was the least in raking 1.94 mN cm^2 g^{-1}. From the previous results, it can be concluded that papers manufactured from *Cupressus sempervirens* as the softwood had the better traits in the tear index than that of hardwood and paper of *Populus alba* were preferable than the other hardwood species. The same trend was found by Kamoga *et al.*[28] on *Cymbopogon nardus*.

Brightness: In this respect, the results of Table 5 obviously cleared that papers produced from *Populus alba* wood was significantly the highest in brightness 79.4% and similarly to that of *Eucalyptus camaldulensis* 79.0%. Whereas the brightness of papers induced from those of *Cupressus sempervirens* and *Acacia nilotica* were similarly 73.6 and 73.7%. It is evident that the traits of brightness papers manufactured from *Populus alba* wood were preferable and over all the other species, followed by that of *Eucalyptus camaldulensis*. Generally, from the above mentioned results, it worthily noticed that paper testing produced from the wood of the used species diverse properties of paper testing, in which *Populus alba* wood produced the best in breaking length. Followed by *Acacia nilotica* and *Cupressus sempervirens* but the breaking length of papers produced from *Eucalyptus camaldulensis* wood was the least in it.

On the other hand, *Populus alba* appeared also the best in burst index followed by papers resulted from wood index followed by papers resulted from wood both *Cupressus sempervirens* and *Acacia nilotica* while those of *Eucalyptus camaldulensis* pronounced the least in burst index. In this respect papers produced from softwood of *Cupressus sempervirens* recorded the superiority in traits of tear index. Consequently that of *Populus alba* wood, then *Eucalyptus camaldulensis,* at last, the papers manufactured from *Acacia nilotica* performed the inferior to that of tear index. The obtained results displayed also that the papers induced from the wood of both *Populus alba* and *Eucalyptus camaldulensis* had the preferable brightness whereas those of *Acacia nilotica* and *Cupressus sempervirens* recorded the lowest one. In general the present study confirmed that the papers manufactured from wood of *Populus alba* have been the most favorable traits more than the other used species, it is due to containing over values of cellulose, holocellulose and hemicellulose and less value of learning.

The aforementioned results of evaluation of paper pulping and tests were discussed by many investigators such as Malinen and Fuhrmann[7], who reported that the brightness of cellulose fibers requires lignin decolorization but not necessary its destruction, except with dissolving pulps, where decolorized lignin interfere chemically and physically with reactions of dissolving filtration etc. Moreover, after the brightness of bleaching pulp strength properties should be acceptable for the end product intended. Also, Jahan *et al.*[8] emphasized the herein obtained results where they reported that *Acacia auriculiformis* pulp tensile, burst index and tear index ranged from 23.4-39.9 N mg^{-1}, from 1.7-1.8 kpa m^2 g^{-1}, respectively, also they found the final brightness of kraft and soda A9 pulp at kappa factor 0.22 was 73.8 and 67.9%, respectively. Also, they added that tensile tears relationship in one of the most important parameters for paper makers. Vennila *et al.*[29] indicated the variability among twenty seven clones in trees, *Eucalyptus* species viz, *Eucalyptus camaldulensis*, *E. teriticornis* and *E. urophylla* were subjected to pulp quality analysis all clones expressed moderate to high range of physical properties in accordance with the herein obtained results which exhibited a steady adverse among the used species as well as Vennila *et al.*[29] reported that strength properties of various clones indicated significant differences ($p \leq 0.05$) among clones viz, tensile index 35-54 N mg^{-1}, burst index 1.9-3.3 kpa m^2 g^{-1} and tear index 3.5-5.6 N m^2 g^{-1}, also, they found that all the identified clones were to be suitable for pulp quality and hence all were included for productivity evaluation. Fuadi and Sulistya[30] reported that a decrease in lignin content means an increase in brightness. Also, Santos *et al.*[11] confirmed that the results showed that pulping quality of *Acacia melanoxylon* trees grown in Portugal is expressed by high pulp yield, low residual lignin and favorable brightness. In addition, Fatriasari *et al.*[31] concluded that the residual lignin content of pulp has a negative correlation with the brightness of *Sorghum bicolor*. Also, Jahan *et al.*[10] reported that *Trema orientalis* had higher alfa-cellulose content and longer fiber length, resulting in higher pulp yield and better papermaking properties. All of those scientists were in the same findings of the herein results and emphasized the present study.

Therefore, it is recommended to use, the local African timber tree species grown in the North of African (Egypt) in manufacturing papers in particular those of *Populus alba* wood where it has been the most favorable paper testing.

CONCLUSION

It is possible, therefore, to be concluded that the *Populus alba* in Egypt would be ideal sources of raw material for pulp and produced papers high quality because of its wood contained less lignin and more amount of cellulose and Hemicellulose.

SIGNIFICANCE STATEMENT

This study discovers the possibility to use, the local wood trees, in Egypt. In addition, this study will help in producing papers that having good properties instead of importation from the abroad, such as *Populus alba* which can be produced papers of high quality.

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