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Investigation of Variations in the Fibre Characteristics of *Moringa Oleifera* (Lam) Stem for Pulp and Paper Production

Ekhuemelo, D.O., and Udo, A. M
Department of Forest Production and Products, University of Agriculture Makurdi,
Benue State, Nigeria.

ABSTRACT

The study assessed fibre characteristics of *Moringa oleifera* (Lam) stem for pulp and paper production. Samples were collected from three *Moringa oleifera* trees of ages 1, 3 and 5 years grown in home gardens in Makurdi. Three samples of sapwood and heartwood portions of the stem were taken from top (90%), middle (50%), and base (10%), respectively. The representative samples were chipped and placed in equal volume of glacial acetic acid and hydrogen peroxide in the ratio of 1:1 for maceration; fibre length, fibre diameter, lumen width and cell wall thickness were measured using Reichert Visopan Microscope and morphological indices were calculated. Data were analyzed using Analysis of Variance (ANOVA). The results show that Fibre length of 1 and 3 years old *Moringa oleifera* were not significantly different. There was no significant difference between the means of Runkel ratio of 3 and 5 years old *Moringa oleifera* but differed significantly from 1 year old *Moringa oleifera* at $P<0.001$. Means of Felting power were not significantly different among 1, 3 and 5year old *Moringa oleifera* at $P<0.005$. There was no significant differences among means of rigidity ratio and F ratio of 1, 3 and 5 years old *Moringa oleifera* tree at $P<0.001$. There was no significant difference among means of top, middle and base portions for 1, 3 and 5 years old *Moringa oleifera* tree. The study found that *Moringa oleifera* is suitable for pulp and paper production and 5 year old *Moringa oleifera* was best suited for pulp and paper production compared to 1 and 3 years old *Moringa oleifera*.

Key Words: *Moringa Oleifera, Fibre Length, Runkel Ratio, Fibre Length, Fibre Diameter, Paper.*

1. INTRODUCTION

Moringa oleifera, commonly called the 'drumstick tree'. It is well known for its multi-purpose attributes, wide adaptability, and ease of establishment. It is a small, fast-growing, drought deciduous tree or shrub that reaches 12m in height at maturity (F/FRED, 1992). *Moringa oleifera* has its origin in Arabia and India. Today the tree is common to landscapes all over the tropics of the Old World—from South Asia to West Africa (Von Maydell, 1989), as well as Central America and the Caribbean (Ramachandran, *et al.*, 1980).

Moringa oleifera is a tropical tree with multiple uses and which is resistant to drought (Fuglie, 1999). According to (Fuglie, 1999), the numerous economic uses of *Moringa oleifera* together with its ease of propagation have raised growing international interest for this tree. Agronomic trails with *Moringa oleifera* show that the plant can grow well in hilly areas, in weathered soils of low fertility.

The Moringa tree is called *Moringa oleifera*, tree of life or miracle tree in English, Okwe-oyibo in Igbo, Zogale bin Hausa, Gerigede in Tiv, Egelengedu in Idoma, Ikon-uwem in Calabar, Rawag in Arabic, Laken in Chinese, Kelor in Indonesia, Shohijan in Nepal, Neverdie in France. It is a fast growing tree and can be planted using the seed or stem cutting. According to (Fuglie, 1999) the many uses of *Moringa oleifera* include alley farming, biopesticides, pulp (wood), robe (bark), tannin for tanning hides (bark and gum) and water purification, medicine, animal forage, ornamental plantings and domestic cleaning agent.

Wood has traditionally been the most widely used lignocellulosic matter in the production of pulp, furniture and boards of diverse types, as well as being a source for energy. Increasing demand for these raw materials, together with economic and environmental factors, makes it necessary to research alternative sources of lignocellulosic matter (Garay, 2002). Paper is one of the most fundamental things that are widely used by many people across the globe. The world consumption of paper has grown 400% in the last 40 years. Nearly 4 million trees or 35% of the total trees cut around the world are used for paper industries on every continent. The world paper consumption was 300 million tons in 1996/1997 and is expected to rise above 400 million tons by the year 2010 (Hurter, 1998). Pulp is a lignocellulosic fibrous material prepared by chemically or mechanically separating cellulose fibers from wood, fiber crops or waste paper. Wood provides about 90% of the basis for pulp production, while about 10% originates from annual plants.

The role of paper and paper products in modern civilization and with increase in the level of literacy cannot be over-emphasized. Paper has assumed a position of almost incredible significance in both developed and developing countries like Nigeria (Onilude, 2011). Paper was first made from non-woody plants and current use of non-wood pulp is included in the grades of paper such as printing and writing papers, liner boards, corrugated medium, newsprint, tissue and specialty paper (Hurter, 2001). But today, more than 95% of paper is made from wood, while the remainder consists of fibrous materials, such as rice chaff, flax and rags. The global consumption of wood is on the increase per year, and there

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has been a continuous research to find an alternative source of fiber for pulp and paper making especially in Africa. In order to remedy the increasing economic difficulties that overdependence on imported pulp fiber has brought to bear on the continent.

So much research work has been done on *Moringa oleifera* for its nutritional qualities, water purification, soil fertility, medicine for various ailments, oil, animal feeds, biopesticides; but no work has been done on its physical and chemical properties to ascertain its suability in pulp and papermaking. It is therefore necessary for researchers to focus more on some agricultural crop alternatives as well as lesser known wood species, exploring their pulping potentials and thus prevents overdependence on the scarce forest resources which is already depleting.

Some of the challenges that necessitated this study include includes shortage of long fibre for pulp and paper industries; demand for paper is on the increase because of population increase development and high rate of literacy level in the country and high cost of importation of pulp and paper products. The objectives of this study therefore is to determine the physical properties of cellulose fibre of *Moringa oleifera* to establish its suitability for pulp production and to compare the physical properties of cellulose fibre of *Moringa oleifera* tree of ages 1, 3, and 5 and know which is best suited for pulp and paper making.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Makurdi, Benue State of Nigeria. Benue State lies within the lower river Benue trough in the middle belt region of Nigeria. Makurdi lies between Latitude 7°38’ N - 7°50’ N, and longitude 8°24’E and 8°38’E. The town lies within the guinea savannah vegetation zone and experiences two distinct seasons, the wet/rainy season and the dry/summer season. The rainy season lasts from April to October with annual rainfall in the range of 100-200mm. The dry season begins in November and ends in March. The temperatures fluctuate between 23-37 degree Celsius in the year (Ministry of Information and Orientation, 2012).

2.2 Method of Sample Collection and Preparation

Wood samples of *Moring oleifera* were collected from felled logs planted in home gardens at Akpehe in Makurdi Local Government Area of Benue State. Three trees were of age 1, 3 and 5 years respectively with straight boles was purposively selected using destructive sampling method. The felling was done with a power chain saw. The diameter of the logs ranged from 10 – 33cm. Wood sample collection was done according to the practice in pulp and paper industries where mixed population of trees and branches of different ages are harvested for pulping rather than those of a particular age. Wood samples were taken by cutting three discs along the bole of the tree, one at the breast height (10%), one at the middle (50%) and the other below the crown (90%). From each of these three discs, two portions from the heart wood and sapwood were collected with cutlass. The samples were chipped and dried at room temperature for two weeks.

2.3 Determination of Fibre Characteristics

Fibre dimensions was determined by reducing representative chips of raw materials into core and was placed into equal volume of glacial acetic acid and hydrogen peroxide in ratio 1:1 in a covered bottle. The solution was placed in the oven for 4 hours at temperature of about 100° for maceration. The macerated cores were disintegrated by shaking the bottle for some days to release the fibre. Random samples of macerated fibres was mounted on slides and examined under a light microscope. Fibres were viewed and measured using a stage micrometer under ×80 magnification. The fibre for each material was mounted on a slide and the fibre length (L), fibre diameter (D), lumen width (d), and cell wall thickness was measured. The following morphological indices (derived values) also called important criteria in papermaking was determined as follows according to Kirci (2006).

i. **Felting power (Slenderness) =**Fibre length ÷ Fibre diameter
ii. **Elasticity coefficient (%) =** Lumen÷ Fibre diameter ×100
iii. **Rigidity coefficient (%) =** Cell wall thickness ÷ Fibre diameter ×100
iv. **Runkel index:** (Cell wall thickness ×2) ÷ Lumen diameter.
v. **F factor =** Fibre length ÷ Cell wall thickness/100

2.4 Statistical Analysis

All data generated was analyzed using two-ways Analysis of variance (ANOVA) and Duncan new multiple range test (DMRT) was used for means separation.

3. RESULTS AND DISCUSSION

A table 1 shows the means of fibre length, fibre diameter, lumen width and cell wall thickness of 1, 3 and 5 years old *Moringa oleifera*. The means of fibre length ranged between 1.20 and 1.28 mm. The results revealed that means of fibre length and lumen width are not significantly different between year 1 and 3 old *Moringa oleifera* but differs significantly from 5 year old *Moringa oleifera* at $P \leq 0.05$. The results further revealed that means of cell wall thickness and fibre diameter significantly different among 1, 3 and 5 year old *Moringa oleifera* at $P<0.05$.

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Table 1: Mean values of fibre dimension of 1, 3 and 5 years old *Moringa oleifera.*

Year	Sampling Height (%) of Stem Portion	N	Fibre Length (mm)	Fibre Diameter (µm)	Lumen Width (µm)	Cell Wall Thickness (µm)
			Mean ± SE	Mean ± SE	Mean ±SE	mean ±SE
1	Top (90%)	6	1.20 ±0.02^a	15.01 ±1.00^a	8.65 ±0.48^a	3.18 ±0.26^a
	Middle (50%)	6	1.21 ±0.02^a	15.01 ±1.00^a	8.81 ±0.48^a	3.11 ±0.26^a
	Base (10%)	6	1.22 ±0.02^a	15.02 ±1.00^a	8.95 ±0.48^a	3.04 ±0.26^a
	Pooled Mean		1.21±0.02	15.01±1.00	8.80±0.48	3.11±0.26
3.	Top (90%)	6	1.26 ±0.02^a	15.05 ±1.00^a	8.90 ±0.48^a	3.84 ±0.26^a
	Middle (50%)	6	1.23 ±0.02^a	15.04 ±1.00^a	8.73 ±0.48^a	3.84 ±0.26^a
	Base (10%)	6	1.20 ±0.02^a	15.03 ±1.00^a	8.15 ±0.48^a	3.73 ±0.26^a
	Pooled Mean		1.23±0.02	15.04±1.00	8.60±0.48	3.80±0.26
5	Top (90%)	6	1.28 ±0.02^a	15.09 ±1.00^a	9.72 ±0.48^a	4.70 ±0.26^a
	Middle (50%)	6	1.28 ±0.02^a	15.08 ±1.00^a	9.53 ±0.48^a	4.63 ±0.26^a
	Base (10%)	6	1.25 ±0.02^a	15.07 ±1.00^a	9.01 ±0.48^a	4.49 ±0.26^a
	Pooled Mean		1.27±0.02	15.08±1.00	9.44±0.48	4.60±0.26

Source: Field Survey 2014

Significance level: 0.05
Mean values in the column with same alphabets are not significantly different

3.1 Fibre Length

The mean value of fibre length obtained in this study shows that top (90%) and middle (50%) portions of 5 year old *moringa oleifera* had the highest mean (1.28mm) of fibre length while top (90%) portion of 1 year and base (10%) portions of 3 year old had the least mean (1.20mm) of fibre length. These fall within the range of 10 - 12 year old stands of *Gmelina arborea* (0.75-1.75m) reported by Rogue and Fo, 2007) and 0.99-1.33mm as reported by Ogunkunle (2010) for 12 *Ficus* species. The values were lower than 1.65-2.33mm reported by Izekor and Fuwape (2011) for 25 year old teak in Eastern Nigeria. For pulp and paper production, species with higher lengths are preferred since a better net will be achieved. Fibre length and distribution has been reported to play important roles in the processing and mechanical performance of fibre-based products such as paper and fiber board (Migneault *et al*., 2008). This is the reason why fibres longer than 1mm as obtained in this study is preferred (Monteoliva *et al*,. 2002, 2005).

3.2 Fibre Diameter

From the result obtained, 5 year old *Moringa oleifera* had the highest (15.08 µm) mean value of fibre diameter while 1 year old *Moringa oleifera* had the lowest (15.01 µm). These fall within the range (14.0-16.0 µm) reported by PPRI, (2011) for eucalyptus and lower than what was reported for *Pinus patula* (36.0-40.0µm). *Gmelina arborea* was reported to have fibre diameter of (18.5-27.5 µm) by Rogue and Fo, 2007). Increase in fibre diameter was reported to be associated with molecular and physiological changes that occur in the vascular cambium as well as the increase in cell walls during the tree growing processes (Plomion *et al*, .2001 and Rogue *et al*, .2007). Based on the results, it shows that *Moringa oleifera* is suitable for pulp and paper production.

3.3 Lumen Width

Lumen width ranged from 8.80-9.44 µm with 5 year old *Moringa oleifera* having the highest (9.44 µm) and 1 year old *Moringa oleifera* the lowest (8.89µm). This is higher than the range (2.47-4.49 µm) reported for some indigenous hardwood species in the tropical rainforest ecosystem (Awuku, 1994); close to 9.87µm for *Leucaena leucocephala* by Ajala (1997); lower than 15.94µm reported for teak by Izekor and Fuwape (2011) and *Gmelina arborea* 13.0µm by Ajala (1997).Generally, the variation in lumen width could be attributed to the increase in cell size and physiological development of the wood as the tree grows in girth. (Rogue *et al*,. 2007) reported a positive relationship in lumen width and cambium age in their study.

3.4 Cell wall thickness

In this study, cell wall thickness ranged from 3.11- 4.60µm with 5 year old *Moringa oleifera* having the highest (4.60µm) and 1 year old *Moringa oleifera* the lowest mean value (3.11µm). This falls within the range (1.94-4.99µm) reported by Ogunkunle (2010) for *Ficus* species; higher than 2.82µm reported for *Gmelina arborea* by Ogunkunle (2010); 2.90µm for *Leucaena leucocephala* by Oluwadare and Ashimiyu (2007) and lower than 5.00-10.00µm reported for pine by PPRI, (2011). The light cell wall makes it easier for delignification and thus confirms the suitability of *Moringa oleifera* as raw material for pulp and paper industries.

Table 2 shows the means of derived indices of 1, 3 and 5 years old *Moringa oleifera* used in the study. Means of runkel ratio was between 0.69 and 0.89. Top (90%) portion of 3 year old and base portion of 5 year old of *Moringa oleifera* had the highest mean (0.89) while Base (10%) portion of 1 year old *Moringa oleifera* had the least mean (0.69).

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Table 2: Means of Derived indices of 1, 3 and 5 years old *Moringa oleifera*

Year	Sampling Height (%) of Stem Portion	N	Runkel Ratio	Felting power/ Slenderness	Elasticity of Coefficient (%)	Rigidity of Coefficient (%)	F. ratio (%)
			Mean ± SE	Mean ± SE	Mean ±SE	mean ±SE	Mean ± SE
1	Top (90%)	6	0.75±0.08[a]	79.95±0.01[a]	57.49±2.00[a]	21.28±1.57[a]	377.36±3.92[a]
	Middle (50%)	6	0.74±0.08[a]	80.61±0.01[a]	58.56±2.00[a]	20.77±1.5[7a]	389.07±3.92[a]
	Base (10%)	6	0.69±0.08[a]	81.23±0.01[a]	59.56±2.00[a]	20.24±1.57[a]	401.32±3.92[a]
	Pooled Mean		0.72±0.08	80.61±0.01[a]	58.53±2.00	20.76±1.57	389.07±3.92[a]
3.	Top (90%)	6	0.89±0.08[a]	83.72±0.01[a]	55.29±2.00[a]	24.42±1.57[a]	328.13±3.92[a]
	Middle (50%)	6	0.88±0.08[a]	81.78±0.01[a]	56.22±2.00[a]	23.93±1.57[a]	320.31±3.92[a]
	Base (10%)	6	0.86±0.08[a]	79.84±0.01[a]	54.39±2.00[a]	22.81±1.57[a]	321.72±3.92[a]
	Pooled Mean		0.87±0.08	81.78±0.01[a]	55.32±2.00	23.72±1.57	323.68±3.92[a]
5	Top (90%)	6	0.86±0.08[a]	84.82±0.01[a]	61.94±2.00[a]	26.13±1.57[a]	272.34±3.92[a]
	Middle (50%)	6	0.86±0.08[a]	84.88±0.01[a]	60.38±2.00[a]	25.83±1.57[a]	276.46±3.92[a]
	Base (10%)	6	0.89±0.08[a]	82.94±0.01[a]	57.68±2.00[a]	25.74±1.57[a]	278.40±3.92[a]
	Pooled Mean		0.87±0.08	84.21±0.01[a]	60.10±2.00	25.90±1.57	276.09±3.92[a]

Source: Field survey 2014

Table 3 shows mean values of morphological properties of stem nature of *Moringa oleifera.* It was observed that heart wood and sap wood of 5 year old *Moringa oleifera* had the highest mean values of fibre length (1.27±0.05 and 1.27±0.02), while heart wood and sap wood of 1 year old *Moringa oleifera* had the lowest mean values (1.19±0.02 and 1.22±0.02). For heart wood, 5 year old *Moringa oleifera* had the highest mean values of Fibre diameter (16.06±0.01) and 1 year old had the least (16.00±0.01). Similarly, for Sap wood, 5 year old *Moringa oleifera* had the highest mean values of Fibre diameter (14.09±0.01) and 1 year old had the lower (14.02±0.01).

Table 3: Mean Values of Morphological Properties of stem nature of *Moringa oleifera*

year	Nature of wood	N	Fibre length	Fibre diameter	Lumen width	Cell Wall Thickness
			Mean ±SE	Mean ± SE	Mean ± SE	Mean ± SE
1 year old	Heart wood	9	1.19±0.02	16.00±0.01	9.61±0.19	3.20±.0.06
	Sap wood	9	1.22±0.02	14.02±0.01	7.10±0.19	3.02±0.06
	Pooled Mean		1.21±0.02	15.01±0.01	8.80±0.19	3.12±0.06
3 year old	Heart wood	9	1.22±0.02	16.03±0.01	8.59±0.19	4.15±0.06
	Sap wood	9	1.24±0.02	14.04±0.01	8.59±0.19	3.45±0.06
	Pooled Mean		1.23±0.02	15.04±0.01	8.09±0.19	3.80±0.06
5 year old	Heart wood	9	1.27±0.05	16.06±0.01	9.44±0.19	4.37±0.06
	Sap wood	9	1.27±0.02	14.09±0.01	9.44±0.19	4.83±0.06
	Pooled Mean		1.27±0.02	15.08±0.01	9.44±0.19	4.60±0.06

Source: Field survey 2014

Table 4 shows mean values of derived indices of stem nature of *Moringa oleifera.* Means of heart wood for runkel ratio was highest in 5 year old (0.81 ±0.02) and lowest in year old and lowest in 1 year old (0.67 ±0.02).For Felting power, mean of 0.08±0.00 was recorded for 1, 3, 5 old *Moringa oleifera.* Elasticity of Coefficient (%) of Heart wood was highest (61.19%) in 5 year *Moringa oleifera* and lowest (60.03 ±1.28 in 1 year old *Moringa oleifera.*

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Table 4: Mean Values of Derived Indices of stem nature of *Moringa oleifera*

Year	Nature of wood	N	Runkel rate	Felting Rate/ Slenderness	Elasticity of Coefficient (%)	Rigidity of Coefficient (%)	F ratio (%)
			Mean ±SD	Mean ± SD	Mean ± SD	Mean ± SD	Means ± SD
1 year old	Heart wood	9	0.67 ±0.02	74.38±0.00	60.03 ±1.28	19.99 ±0.39	371.88±0.52
	Sap wood	9	0.77 ±0.02	87.01±0.00	57.04 ±1.28	21.53 ±0.39	403.97±0.52
	Pooled Mean		0.72±0.02	80.61±0.00	58.53±1.28	20.76±0.39	387.82±0.52
3 year old	Heart wood	9	0.77 ±0.02	76.10±0.00	57.04 ±2.28	21.53 ±0.39	293.98±0.52
	Sap wood	9	0.97 ±0.02	88.31±0.00	53.60 ±1.28	25.91 ±0.39	359.42±0.52
	Pooled Mean		0.87±0.02	81.78±0.00	55.32±1.28	23.72±0.39	323.68±0.52
5 year old	Heart wood	9	0.81 ±0.02	79.07±0.00	61.19 ±1.28	24.57 ±0.39	290.62±0.52
	Sap wood	9	0.93 ±0.02	90.13±0.00	58.80 ±1.28	27.23 ±0.39	262.94±0.52
	Pooled Mean		0.87±0.02	84.21±0.00	60.00±1.28	25.90±0.39	276.09±0.52

Source: Field survey 2014

4. DERIVED VALUES (MORPHOLOGICAL INDICES)

4.1 Runkel Ratio: The runkel ratio of wood is one of the properties that have been recognized as important traits for pulp and paper properties (Ohshima *et al*, .2005). It is related to paper conformity and pulp yield. The runkel ratios obtained in this study for 1, 3 and 5 years old *Moringa oleifera* are less than 1 (0.72-0.87) and falls within the range 0.79 reported by Ajala (1997) for pine spps, 0.75 by Awuku (1994) for some tropical hardwood species but less than 0.99 reported for *Anthonatham acrophylia* and *Dalium guineensis* in Nigerian rainforest (Ezeibekwe *et al*,.2009). Runkel ratio should be <1 for wood with good quality for pulp production (Kpikpi, 1992) thus, *Moringa oleifera* is a suitable raw material for pulp and paper production since runkel ratio is <1. Means of Runkel ratio of 1 year old *Moringa oleifera* differed significantly from 3 and 5 year old *Moringa oleifera*, but there was no significant difference between the mean of Runkel ratio of 3 and 5 year old *Moringa oleifera* at P<0.05.

4.2 Felting power/Slenderness

One of the criterions that control suitability of wood material to paper production is felting power calculated by comparing fiber length to diameter (Akgul, 2009). Felting power is an important factor which has positive effect on strength, tear, burst, breaking off; double folding resistance according to physical test results of the paper. Felting power required for good paper is between 70-90 for softwoods and 40-60 for hardwoods. This rate was measured as 75.68 for wheat stem(Eroglu, 1980) and 59.6 for tobacco stem (Tank, 1980). Generally, the acceptable value for Felting power (slenderness ratio) for papermaking is more than 33 (Xu *et al*, .2006). 1, 3 and 5 years old *Moringa oleifera* falls within the ranges of 79.84 - 84.88 which shows that it is suitable for paper making. For Felting power, there was no significant difference among the means of 1, 3 and 5 year old *Moringa oleifera* at P>0.05

4.3 Elasticity coefficient (%)

There are four groups of fibres (Bektas, *et al*, .1999): High elastic fibres (EC greater than 75); elastic fibres (EC between 50 -75); rigid fibres (EC between 30-50) and highly rigid fibres (EC less than 30). For this study *Moringa oleifera* falls within elastic fibres (54.39 - 61.94)%, thus fibres of this tree can be stretched making it a suitable raw material for papermaking as longer fibres are usually preferred for papermaking in other to get high resistance. Means of Elasticity of Coefficient of 1 and 5 year old *Moringa oleifera* were significant different (P>0.05) but different significantly from 3 year old.

4.4 Rigidity Coefficient (%)

The values of RC obtained in this study ranged from 20.24% - 26.13% for *Moringa oleifera*. This falls within the range reported by (Hus *et al*,.1975) for juvenile beech wood 22.95 and 27.66 for eucalyptus. High rate of rigidity coefficient affects tensile, tear, burst and double fold resistance of paper negatively (Hus *et al*,. 1975). This implies that the low rigidity coefficient rate of *Moringa oleifera* makes it suitable as raw material for pulp and papermaking. The result also revealed that there were significant differences among means of Rigidity of Coefficient and F ratio for 1, 3 and 5 years old of *Moringa oleifera* stem at P<0.05.

4.5 F ratio (%)

Bigger F factor (276.09 - 389.07) % calculated by dividing fiber length into wall thickness determines that flexibility of papers obtained from this study will be good for paper mking. F factor for beech juvenile wood was found as140.38, it was found as 240.55 for black pine juvenile wood(Akgul, 2009). On studies about hardwoods, F factor was found as 235.92 for *Populus euramericana* and 206.78 for *Populus tremula* (Kar, 2005). On other studies related with softwoods, F factor was found as 606.66 for *Pinus brutia*, 410.34 for *Cedrus libani* (Erdin, 1985), spring wood radial for *Pinus*

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pinaster (Izmit, land, Bonitet-1) was determined as 745.40, spring wood tangent as 695.81, summer wood radial as 603.9 and summer wood tangent as 493.20 (As, 1992).

In this study, 5 year old *Moringa oleifera* had the highest fibre length, fibre diameter, lumen width and cell wall thickness 1.27, 15.04, 9.44 and 4.60 while 1 year old *Moringa oleifera* had the lowest 1.21, 15.01, 3.01 for fibre length, fibre diameter and cell wall thickness, and 3 year old *Moringa oleifera* had the lowest 8.80 for lumen width.

For Runkel ratio, Felting power, Elasticity coefficient, Rigidity coefficient 5 year old *Moringa oleifera* had the highest and 1 year old *Moringa oleifera* had the highest for F ratio 38.95 while 1year old *Moringa oleifera* had the lowest for Runkel ratio, Felting power and rigidity coefficient and 3 year old *Moringa oleifera* had the lowest for elasticity coefficient. It shows that 5 year old *Moringa oleifera* is best suited for pulp and paper production compared to 1 and 3 years old *Moringa oleifera.*

5. CONCLUSION

From the results of this work, *Moringa oleifera* stem can be used for pulp and papermaking. Based on its appreciable fibre lengths and Runkel ratio, *Moringa oleifera* is pulpable and can therefore be used in pulp and paper production. 5 year old *Moringa oleifera* was best suited for papermaking compared to 1and 3 year old *Moringa oleifera*. There was no variation in the means of sapwood and heartwood. That implies that they were both good for pulp and papermaking.

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