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Fibre Characteristics of The Trunk of Citrus Sinensis (L.) Osbeck

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Abstract: *The fibre characteristics of the trunk of Citrus sinensis (L) Osbeck have been studied with the aim of discovering another usefulness of the species other than as sources of vitamins A and C.*
A fully grown tree of Citrus sinensis (sweet orange) within the range of 35-40 years old was felled in an open forest in Jericho town, Ibadan, Oyo-state at the diameter of chest height (1.3 meters above ground level) and thereafter taken to wood saw mill were the trunk was subdivided into circular discs to represent basal, middle and top regions of the trunk. The discs were further taken to the Department of Wood Technology and Utilization (WT & U) of the Forest Research Institute of Nigeria (FRIN), Ibadan, Nigeria for maceration of wood samples and preparation of slides of wood fibers. The lengths, diameters, lumen diameters & cell wall thickness of the fibres in the trunk were measured in micrometers (µm). Data were collected from averages of 50 measurements and subjected to statistical analysis such as ANOVA.

The values obtained were used to determine the fibre Runkel's ratio using standard formulas. The average length and diameter of fibre in the entire trunk of this species were 558.05± 142.45 and 10.61±1.60.These low figures placed the fibres obtained in the present study under the very short group of fibres. The average length of fibres in the axial direction were 508.96±128.42 ,610.21±158.27 and 555.00± 121.63 for the base, middle and top regions respectively, whereas, they were 550.79±146.56,517±113.70 and 606.17±151.83 in the radial direction for the core, middle and outer regions respectively. Significant variations (P ≤ 0.05) existed in the length of fibres both in the axial and radial direction of the trunk from base to top as well as from core to outer portions respectively. On the other hand, the average diameters of fibre in the trunk along the axial direction were 10.29 ± 1.99, 9.10 ± 0.58 and 9.90 ± 1.85 for the base, middle and top regions of the trunk respectively, whereas, the values along the radial directions were 10.17 ± 2.09, 9.83 ± 1.13 and 10.18 ± 1.44 for the core, middle and outer regions of the trunk respectively. Insignificant variations (P ≤ 0.05) existed both along the axial and radial regions of the trunk. The Runkel's ratio for the fibre in the trunk of this species was determined to be less than 1 which makes it a useful alternative source of raw material for the production of pulp and paper. It was recommended that the chemical analyses of the trunk of this species be urgently carried out along side with flexibility coefficient, slenderness ratio and Luce's shape factor of the fibres in other to provide more information about the quality of pulp and paper products derivable from the trunk of this species.
Key words: *fibres, length, diameter, pulp, paper, trunk, Citrus sinensis.*

I. Introduction

Citrus sinensis, orange or sweet orange(to distinguish it from related species, such as sour orange, C. aurantium and mandarin orange, C.reticulata),is a small tree in the Rutaceae (Citrus family) that originated in Southern China, where it has been cultivated for millennia. Oranges, which are high in vitamins A and C and potassium, are eaten fresh or processed into juices, which can be consumed directly or further processed into concentrate, both used in numerous soda and cocktail drinks, punches, orangeades, and liqueurs (although many orange liqueurs are made from sour, rather than sweet oranges, or from a combination).

The orange tree is small, spiny tree, typically growing to 7.5m (25ft), but occasionally reaching heights up to 15m (50ft), generally with a compact crown. Leaves are leathery and evergreen, and range from elliptical to oblong to oval, 6.5-15cm and 2.5-9.5cm wide, often with narrow wings on the petioles (leaf stems). The fragrant white flowers, produced singly or in cluster of up to 6 are around 5cm wide, 5 petals and 20 to 25 yellow stamens. The fruit, which may be globose to oval, is typically 6.5 to 9.5 cm wide, and ripens to yellow to orange. The fruit skin (rind or peel) contains numerous small oil glands. The flesh or pulp of the fruits is typically juicy and sweet, divided into 10 to 14 segments (although there are seedless varieties) and ranges in color from yellow to orange to red (Vogel, 2003).

Oranges are now grown commercially worldwide in tropical, semi-tropical, and some warm temperate regions, and have become the most widely planted fruit tree in the world. In Nigeria, about 3,900,000 tonnes of Citrus fruits were produced from an estimated hectarage of 800,000 hectares of land in 2012 (FAO, 2012). Citrus is grown in the rain forest and guinea savannah, most of these farmlands are in the remote part of the country. There are two main markets for Citrus fruit in Nigeria: the fresh fruit market and the processed Citrus fruits market (mainly orange juice)(Olife et. al. 2015).

According to Saeed et. al.(2010), the physical properties of stem and root are related to their anatomy and there is no way to interpret their role without sufficient knowledge of their structure(Beakbane and Thompson, 1939; Beakbane and Thompson, 1947; Mckenzie, 1961 and Miller et al., 1961). Consequently, previous researchers such as Gill and Ogulowo (1988), Gill and Onuja (1988), Gill and Okoegwale (1990) and Gill et. al.(1991) reported their scientific discoveries about the fibres and other anatomical features of trunk or stem of some different woody plant species in relation to their possible end uses. More recently, Otoide (2013) reported the presence of libriform, non-septate and medium sized fibres in the stem of a fully grown species of Adansonia digitata. In the same vein, Sharma et. al. (2013) evaluated the characteristics of fibers in some weeds of Arunachal Pradesh, India for pulp and paper making. Similarly, Otoide (2014) studied the fibres in the stem of Afzelia africana by measuring their lengths and diameters in micrometer. He reported extremely short nature of fibres and recommends that the species be exploited for construction works and any other production in which woods with extremely short fibre length will not negatively affect the end product of productions.

From the foregoing, information about the fibre in the trunk of tropical woody species is very scanty and the available ones are not properly documented. This present study seeks to provide additional information on the fibre characteristics of Citrus sinensis (sweet orange) and confirm its usage for pulp and paper making for the first time.

II. Materials And Methods

Collection Of Materials

A fully grown tree of Citrus sinensis (Sweet Orange) within the age range of 35-40 years old was felled at the diameter at chest height (1.3meters above ground level), from an open forest in Jericho environs of Ibadan, Nigeria. The trunk was thereafter taken to the Department of Wood Technology and Utilization (WT&U) of the Forest Research Institute of Nigeria (FRIN), Ibadan, Nigeria for identification and microscopic preparations of slides of fibres.

Experimental Procedures And Maceration Of Wood Samples

The procedures used in this study strictly followed Otoide (2014). The bole length of the felled tree was measured with the aid of a measuring tape from the level of chest height to the crown and the value was 1.10meters. Thereafter, transverse disc of 20cm thick axially was cut from the base, middle and the top of the trunk. A total of three transverse discs was cut out of the entire trunk. Each of the discs was divided longitudinally into two semi-circular hemispheres with the line of division passing through the pith. One of the two semi-circular hemispheres was tagged as the Northern hemisphere and the other one, the Southern hemisphere. Only the Northern semi-circular hemispheres were used for the whole of the experiments while the Southern semi-circular hemispheres were discarded. The base, middle and the top semi-circular hemispheres were further divided into three regions, with the lines of division parallel to the equator, which passes through the centre of the pith. These three regions were labeled as:

- CORE (C),
- MIDDLE (M) and
- OUTER (O).

Five blocks of the dimension, 2cm x 2cm x 2cm and another five blocks of the dimension, 2cm x 2cm x 6cm cut out of the core, middle and outer blocks earlier extracted from the three semi-circular hemispheres, each of which was cut out from the base, middle and the top of the trunk. On the base disc, five replicate extracts, each from the core, middle and the outer regions of the semi-circular hemisphere were cut out, making a total of 15 blocks of the dimension, 2cm x 2cm x 2cm and also a total of 15 blocks of the dimension, 2cm x 2cm x 6cm. A total of 30 blocks were extracted separately from the Base, Middle and the Top of the trunk. Ground total of 90 blocks of wood pellets was extracted from the whole of the tree trunk/log. All the 90 blocks of wood pellets were used for the whole of the experiments involved in the study.

Maceration Of Wood Samples

In order to determine the length and diameter of fibres in the log(Stem) of this species, the method outlined by Otoide (2014) was followed.

Thin slivers of wood materials were removed from the whole of the 2cm x 2cm x 2cm blocks and placed in separate test tubes containing mixture of equal amount of hydrogen peroxide and acetic acid (i.e. in ratio 1:1) individually, such that no silvers of different blocks were placed together in a test tube. The test tubes were then placed inside an electric oven for 4 hours at 80^oC. The test tubes were then removed from the oven and shaken properly so as to defibrize the slivers. The test tube samples were then dropped on clean cover slides with the aid of a pipette and the slides were viewed under a calibrated microscope. Length and diameter measurements of fibres were averages of 50 measurements.

III. Experimental Design

The Experimental Design adopted for this work is a two Factorial in a Complete Randomized Design (C.R.D) with different replications of the test Samples.

FACTOR A: The longitudinal direction (Base, Middle and Top) of the trunk.

FACTOR B: The radial directions, where the sample sticks were collected (The Core, Middle and Outer) region of the trunk.

Statistical Analysis

Analysis of Variance (ANOVA) was conducted to test the relative importance of various sources of variation on the length(µm) and diameter(µm) of the fibres. The main effects considered were differences along the longitudinal (i.e. Axial) and Radial Positions. The Follow up test was conducted, using Duncan Multiple Range Test (D.M.R.T). This was done to know the significant difference between the two Means at $P \leq 0.05$.

The mathematical Model for the two Factors factorial experiment is given as:

Yij = u + Ai + Bj + (AB)ij + Eij

Where:

µ = General mean of individual observation;

Ai = Effect of Factor A;

Bj = Effect of Factor B;

(AB)ij = Effect of interaction between Factor A and B;

Eij = Effect of interaction Error term.

IV. Results

The results obtained in this study have been summarized in Tables 1-5. The average length (µm) of fibres along the axial direction of the trunk were 508.96±128.42, 610.21±158.27 and 555.00±121.63 for the base, middle and top regions respectively, while they were 550.79±146.56, 517.20±113.70 and 606.17±151.83 along the radial direction for the core, middle and outer regions respectively(Table 1). There existed significant variations ($P \leq 0.05$) in lengths of the fibres both along the axial and radial directions of the trunk. In the same vein, the average diameter (µm) of the fibres along the axial direction of the trunk were 10.29±1.99, 9.10±0.58 and 9.90±1.85 for the base, middle and top regions respectively, while along the radial direction they were 10.17±2.09, 9.83±1.13 and 10.18±1.44 for the core, middle and outer regions respectively(Table 2). Insignificant variations ($P \leq 0.05$) existed in the average diameter of the fibres both in the axial and radial directions of the trunk. The fibre lumen on the other hand, had average diameters (µm) of 7.00±2.10, 6.88±0.96 and 6.62±1.78 for the base, middle and top regions along the axial direction of the trunk respectively. There were insignificant variations ($P \leq 0.05$) in lumen diameters both along the axial and radial directions of the trunk (Table 3). In the same vein, the average thickness (µm) of fibre cell walls along the axial direction of the trunk were 1.64 ±0.38, 1.56±0.40 and 1.64±0.43 for the base, middle and top regions while they were 1.70±0.42, 1.58±0.40 and 1.56±0.39 for the core, middle and outer regions along the radial directions of the trunk respectively. Insignificant variations ($P \leq 0.05$) existed in the thickness of the cell walls of fibres along both the axial and radial directions of the trunk (Table 4).

Furthermore, the average runkel ratio for the fibres in the trunk of this species is 0.50±0.20. Insignificant variations ($P \leq 0.05$) existed in the Runkel[s] ratio along the axial and radial directions of the trunk as 0.51±0.20, 0.50±0.20 and 0.53±0.20 were determined for the base, middle and top regions along the axial directions respectively while 0.54±0.21, 0.50±0.20 and 0.50±0.20 were determined for the core, middle and outer regions respectively(Table 5).

Table 1 : Average Length (µm) Of Fibres Along The Axial And Radial Axes Of The Trunk Of Citrus Sinensis.

AXIAL AXES	RADIAL AXES			
	CORE	MIDDLE	OUTER	AXIAL MEANS
BASE	547.93 ± 114.22	441.12 ± 99.45	537.83 ± 144.77	508.96 ± 128.42^{a}
MIDDLE	604.49 ± 178.77	540.86 ± 83.96	685.29 ± 166.58	610.21 ± 158.27^{b}
TOP	449.95 ± 126.21	569.64 ± 116.75	595.40 ± 106.06	555.00 ± 121.63^{c}
RADIAL MEANS	550.79 ± 146.56^{b}	517.20 ± 113.70^{c}	606.17 ± 151.83^{a}	558.05 ± 142.45

Means with different letters in the column and row are significantly different at $P \leq 0.05$

Table 2 : Average Diameter (µm) Of Fibres Along The Axial And Radial Axes Of The Trunk Of Citrus Sinensis.

AXIAL AXES	RADIAL AXES			
	CORE	MIDDLE	OUTER	AXIAL MEANS
BASE	10.60 ± 2.30	9.85 ± 0.86	10.40 ± 2.50	10.29 ± 1.99^{a}
MIDDLE	9.10 ± 0.45	9.85 ± 0.72	10.15 ± 0.52	9.10 ± 0.58^{a}
TOP	9.90 ± 2.80	9.80 ± 1.64	9.10 ± 0.31	9.90 ± 1.85^{a}
RADIAL MEANS	10.17 ± 2.09^{b}	9.83 ± 1.13^{b}	10.18 ± 1.44^{b}	10.61 ± 1.60

Means with the same letters in the column and row are not significantly different at P≤0.05

Table 3 : Average Length (µm) Of Fibre Lumen Along The Axial And Radial Axes Of The Trunk Of Citrus Sinensis.

AXIAL AXES	RADIAL AXES			
	CORE	MIDDLE	OUTER	AXIAL MEANS
BASE	7.40 ± 2.27	6.46 ± 1.15	7.17 ± 2.58	7.00 ± 2.10^{b}
MIDDLE	6.67 ± 0.83	6.77 ± 1.04	7.22 ± 0.94	6.88 ± 0.96^{b}
TOP	6.26 ± 2.61	6.77 ± 1.40	6.82 ± 0.92	6.62 ± 1.78^{b}
RADIAL MEANS	6.77 ± 2.07^{a}	6.67 ± 1.19^{a}	7.07 ± 1.65^{a}	6.83 ± 1.68

Means with the same letters in the column and row are not significantly different at P≤ 0.05

Table 4 : Average Thickness (µm) Of Fibre Cell Wall Along The Axial And Radial Axes Of The Trunk Of Citrus Sinensis.

AXIAL AXES	RADIAL AXES			
	CORE	MIDDLE	OUTER	AXIAL MEANS
BASE	1.62 ± 0.42	1.70 ± 0.38	1.62 ± 0.35	1.64 ± 0.38^{c}
MIDDLE	1.67 ± 0.37	1.54 ± 0.45	1.46 ± 0.36	1.56 ± 0.40^{c}
TOP	1.82 ± 0.45	1.52 ± 0.37	1.60 ± 0.44	1.64 ± 0.43^{c}
RADIAL MEANS	1.70 ± 0.42^{c}	1.58 ± 0.40^{c}	1.56 ± 0.39^{c}	1.61 ± 0.40

Means with same letters in the column and row are not significantly different at P ≤ 0.05

Table 5: Average Runkel Ratio Of Fibres In The Trunk Of Citrus Sinensis

AXIAL AXES	RADIAL AXES			
	CORE	MIDDLE	OUTER	AXIAL MEANS
BASE	0.47 ± 0.20	0.60 ± 0.21	0.50 ± 0.20	0.51 ± 0.20^{a}
MIDDLE	0.52 ± 0.18	0.50 ± 0.20	0.42 ± 0.20	0.50 ± 0.20^{a}
TOP	0.64 ± 0.23	0.50 ± 0.13	0.50 ± 0.20	0.53 ± 0.20^{a}
RADIAL MEANS	0.54 ± 0.21^{c}	0.50 ± 0.20^{c}	0.50 ± 0.20^{c}	0.50 ± 0.20

Means with the same letters in the column and row are not significantly different at P≤ 0.05

V. Discussion

Averages of 558.05±142,45µm and 10.61±1.60µm as well as 6.83±1.68µm and 1.61±0.40µm were determined as the fibre length, fibre diameter, lumen diameter and fibre cell wall thickness of the trunk of Citrus sinensis used in the present study. Metcalfe and Chalk (1985) reported that the length of fibres in dicotyledons ranges from 150-3350µm. The average length of fibres determined (558.05µm) in the trunk of Citrus sinensis is within this range. This further confirms the taxonomic status of this species as a dicotyledon.

Similarly, following the terminology and classification standard of Metcalfe and Chalk (1985) on fibres, it is interesting to say here that, the fibres in the trunk of Citrus sinensis were very short (558.05µm) being within the range of 500-700µm. The average diameter of fibres (i.e. 10.61 ± 1.60) determined for this species falls within the range (i.e. 10 to 50µm) specified by Metcalfe and Chalk (1985).

According to Sharma et. al. (2013), Fibres are narrow, elongated sclerenchyma cells with lignified wall and provide support to plants. Morphological characteristics of fibre like length and width are important parameters to estimate the pulp quality. In addition, cell wall thickness and lumen size also affect the rigidity and strength of paper. They further reported that the fibers with Runkel's ratio less than 1 are good for paper making because fibers are more flexible, collapse easily and form a paper with large bonded area while, fibers with Runkel's ratio more than 1 are stiff, difficult to collapse and form bulkier paper with less bonded area(Jang and Seth, 1998 and Dutt et. al., 2009). Consequently, the Runkel's ratio for the fibres in the present study was determined to be 0.50 ± 0.20 (Table 5). This figure is less than 1. Going by the reports of the researchers above, it is pertinent to say here that, the trunk of Citrus sinensis (Sweet Orange) be recommended as alternative source of raw material for pulp and paper making. In the same vein, The diameter of fibre lumen in the trunk of this taxon was determined to decrease with increase in plant height from base to top of the trunk. This is in line with the previous report of Otoide (2014) about the fibre lumen in the trunk of Afzelia africana in the fibre lumen decreased from base to top of the trunk. According to Sharma et. al. (2013), Luce's shape factor is an important fiber index and derived from fiber diameter and lumen diameter. It is directly related to paper sheet density. Lumen diameter is also an important factor in the determination of flexibility coefficient of paper.

The worldwide recognition of the fruit of Citrus sinensis popularly known as sweet orange as affordable and natural source of vitamins A, C and Potassium has blurred the recognition of other parts of the plant such as the trunk and the leaves as important source of raw materials for industries. Even, scientific research is, nowadays, more focused on the fruit and leaf of this plant (Citrus sinensis) than the trunk especially for their medicinal importance. This present study has attempted to bridge the gap between the trunk of this species and consumers as well as pulp and paper industry by revealing the possible end use of the trunk of this species via the wood fibres.

VI. Conclusion:

Early research gave the general belief that only long-fibered wood species are suitable for pulp and paper making (Richard, 1978). However, subsequent studies have shown that fibre length is not the overriding factor in producing paper with the desired quality and strength .

If the general early general belief mentioned above was to be upheld for Citrus sinensis, it would not be a recommendable alternative source of raw material for pulp and paper production because of the very short nature of the trunk fibre so reported in the present study. Interestingly, the present study revealed that the Runkel's ratio of the trunk fibres was less than 1. Recent scientific research has borne the general belief that wood species with fibre having Runkel' ratio that is less than 1 are suitable for pulp and paper making.

In view of the above, it is pertinent to say here that, the trunk of this economic crop plant (Citrus sinensis) is recommendable as alternative source of raw material for pulp and paper making by virtue of the fibre Runkel' ratio presented in the present report.

VII. Recommendation:

The chemical analyses of the trunk of the species used in the present study should be urgently carried out along side with the slenderness ratio, flexibility coefficient and Luce's shape factor of the fibre. These will provide information about the quality of paper products from the species in question.

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