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Evaluation of Organic Carbon, Ash and Nitrogen Content in White Mangroves (*Laguncularia racemosa*) from Central and Western Regions of Ghana

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Abstract
When wood is used as fuel by burning, nitrogen dioxide (NO_2) may be formed, and NOx can enrich forest soil. However, it has a negative impact on health from the emission of high levels of NOx, including acidification of water and soils. Carbon content contributes significantly to the heating value of wood fuel, with higher carbon content giving a higher heating value. This study aimed to determine the organic carbon, nitrogen and ash content in White Mangroves (*Laguncularia Racemosa*) from Ghana's Central and Western Regions. *L. racemosa* generally showed low organic carbon, ash and nitrogen content values. The study showed 30.72 – 31.52% and 30.52 – 31.56% (organic carbon), 2.39 – 3.26% and 2.62 – 2.94% (ash), and 223.41 – 300.32 mg/Kg and 199.55 – 242.66 mg/Kg (nitrogen) in mangrove samples from Central and Western regions respectively.

Keywords
White Mangrove; Ash Content; Organic Carbon Content; Nitrogen Content; Heartwood; Sapwood

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Contents

1. Introduction

The knowledge of organic carbon, ash and nitrogen levels in plants is very useful for the effective use of any plant. According to Meier et al. (2013), when wood is burned for fuel, nitrogen oxide (NO_2) may be formed through the oxidation of nitrogen in the wood. Mitchual et al. (2014) indicated that nitrogen oxides (NOx) are beneficial since they can enrich forest soils. However, negative impacts on health from the emission of high levels of NOx, including acidification of water and soils (Mitchual et al., 2014) and the risk of respiratory infections (Sillman, 2003) have been reported. Photochemical smog can be formed when NOx reacts with volatile organic compounds in the presence of sunlight and thus pollute the air (Sillman, 2003). Mitchual et al. (2014) indicated that carbon content contributes significantly to the heating value of wood fuel, with higher carbon content giving higher heating values.

According to Meier et al. (2013), carbon is the major constituent of wood, making up 45 to 50% of its biomass. The content of carbon, nitrogen and ash in plants is influenced by many factors. According to Kollmann (1959) and Campbell et al. (1990), factors that influence the amount and composition of ash include the season, weather conditions, and soil mineral availability.

Wood portions with higher densities result in an increase in the percentage of ash content as a result of the conversion of sapwood into heartwood from the bottom to the top portion of the tree, thus giving the bottom portion (with more heartwood and higher density) higher ash content than the top portion of the tree (Nurfaizah et al., 2014). Differences in carbon content between different parts of trees are small in relation to the range of variations in overall carbon content (Matthews, 1993). Ash content varies greatly within trees, highest at the heartwood and decreasing towards the bark (Imbeah, 1999). Mangroves are ecosystems that provide essential goods

and services to human communities living in coastal areas. The benefits of mangroves include harvesting wood and non-wood products, fisheries, recreation, ecotourism, bio-filtration, coastal protection and carbon sequestration (Spalding et al., 2010). This study aimed to determine the organic carbon, nitrogen and ash content in *Laguncularia Racemosa* (White Mangroves) from the Central Region (CR) and Western Region (WR) of Ghana.

2. Materials and Method

2.1 Experimental

Matured *laguncularia racemosa* trees measuring 14-16 m in length and 30 cm in diameter were selected from Ghana's Central and Western regions. The felled *Laguncularia racemosa* (white mangrove) boles were divided into three sections: the base, middle and top.

2.2 Sample preparation

2 x 2 x 2 cm discs were cut from air-dried, defect-free billets prepared from each section of the trees from the two regions and labelled accordingly. Defect-free, air-dried samples from each section were made into small chips and further milled with a high-speed laboratory blender and sieved with a 250 µm sieve.

2.3 Determination of ash content

ASTM D 1102-84 (2007) standard was used to determine the ash content. An empty crucible was first ignited in a muffle furnace at 600ºC, cooled in a desiccator, and weighed to the nearest 0.1 mg. 2 g air-dried wood samples were weighed into different pre-weighed crucibles and placed in an oven at 103 ± 2ºC, then, cooled in a desiccator and weighed. The heating and cooling were repeated until the weight was constant. The crucibles and contents were then placed in the muffle furnace at 600ºC for 4 hours to burn off all the carbon. The sample was heated slowly at the start to avoid flaming while protecting the crucibles from strong draughts at all times to avoid mechanical loss of the test specimen. The temperature of the final ignition was 600ºC. The crucibles, with their content, were then placed in a desiccator to cool and weigh. The heating was repeated until a constant weight of not more than 0.2 g was obtained after cooling. The ash content was calculated as in equation 1.

$$Ash(\%) = M_1 \times 100/M_2 \quad (1)$$

Where: M_1 = Weight ash M_2 = Weight of oven-dried sample.

2.4 Determination of organic carbon (C) content

The organic carbon content of the wood samples was determined by the Walkley – black wet oxidation method (Nelson & Sommers, 1982; Heanes, 1984). 0.1g samples from each of the three sections from the two regions were weighed into separate 500 mL Erlenmeyer flasks, followed by the addition of 10 mL of 1.0 N potassium dichromate solution and 20 mL of concentrated H_2SO4. Each sample mixture was swirled to ensure that the solution was in contact with all the particles of the wood samples. The flasks and their content were allowed to cool on an asbestos sheet for 30 minutes, after which 200 mL of distilled water and 10 mL of orthophosphoric acid were added. 2.0 mL (of 10 mL) of diphenylamine indicator was added, and the resulting solution was titrated with 1.0 N ferrous sulphate solution until the colour changed to blue and then finally to green. A blank determination was made, and the carbon content of the samples was determined by the formula shown in equation 2.

$$\%OrganicC = Blank - (T \times N) \times 0.3/Weightofsample \quad (2)$$

Where: Blank= Titre value for blank ($\geq$ 10.5). T= mL of $FeSO_4$ used for titration (titre value) N = Normality of $FeSO_4$

2.5 Determination of nitrogen (N) content

The nitrogen content of the wood samples was determined by the Kjeldahl method (Bremner & Mulvaney, 1982). 2g air-dried samples from sections of the trees were separately weighed into different 500 mL long-necked Kjeldahl flasks, and 10 mL distilled water was added to moisten the samples. A spatula full of Kjeldahl catalyst (mixture of 1-part selenium + 10 parts $CuSO_4$ + 100 parts $Na2SO_4$) was added, followed by 20 mL concentrated H2SO4. The solution was placed in a macro Kjeldahl digestion unit to digest until the solution was clear and colourless. The flask was allowed to cool, the fluid was decanted into 100 mL volumetric flasks, and distilled water was added. An aliquot of 10 mL was transferred from the digested sample using a pipette into the Kjeldahl distillation flask, and 90 mL of distilled water was added to make up to 100 ml in the distillation flask. An additional 20 ml of 40% NaOH was added to the content of the distillation flask and distillate collected over 10 mL of 4% boric acid containing 3 drops of mixed indicator in a 200 mL conical flask. A light blue colour was observed due to the presence of nitrogen. 100mL of distillate was titrated with 0.1 N HCl until the blue colour changed to grey and then to pink. A blank determination was carried out. The Nitrogen content (N_c) of the samples was determined using the formula in equation 3.

$$\%N_c = \frac{14 \times (A - B) \times N \times 100}{1000 \times 0.2} \quad (3)$$

Where: A = volume of standard HCL used in sample titration B = volume of standard HCL used in blank titration N = normality of standard HCL

$$\%N_c = \frac{2g \times 10mL}{100mL} = 0.2g \quad (4)$$

3. Results and Discussion

3.1 Evaluation of organic carbon content

Figure 1 shows the mean organic carbon content of *Laguncularia racemosa* samples from CR and WR.

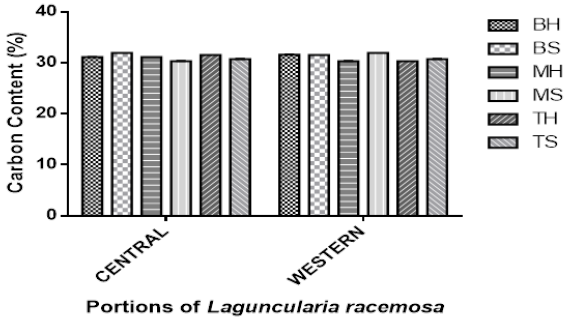

Figure 1. Mean Organic Carbon Content of *Laguncularia racemosa*

BH = Heartwood of Base, BS = Sapwood of Base, MH = Heartwood of Middle, MS = Sapwood of Middle, TH = Heartwood of Top, TS = Sapwood of Top.

Figure 1 shows that WR samples recorded the greatest organic carbon content at the middle (31.92%) and lowest at its top (30.72%) along the sapwood. The heartwood recorded the highest at the base (31.59%), and the middle and top recorded the same (30.32%). Along the sapwood of trees from CR, the base recorded the greatest value (31.92%) and lowest at its middle (30.32%). The heartwood recorded the greatest at the top (31.52%) and least at both the base and the middle recorded the same (31.12%)(Figure 1).

Figure 2 shows the mean carbon content along the Stem (heartwood and sapwood portions) of *Laguncularia racemose*.

CB = Central Base, CM = Central Middle, CT = Central Top, WB = Western Base, WM = Western Middle, WT = Western Top. The overall organic carbon content along the stem (Figure 2) indicates the base recorded the highest value (31.52 and 31.56%, CR and WR, respectively) and lowest at the middle (30.72%) and top (30.52%) for CR and WR respectively. There was a significant difference in mean carbon content ($p < 0.05$) for the various portions along the stem. According to Meier et al. (2013), carbon is the major constituent of wood, making up 45 to 50% of its biomass. From the study, the organic carbon content (sapwood and heartwood) along the stem ranged from 30.72 – 31.52% for CR and 30.52 – 31.56% for WR. According to Matthews (1993), differences in carbon content between different parts of trees

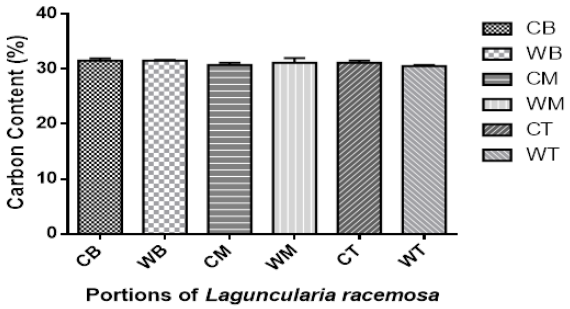

Figure 2. Mean Carbon Content along the Stem (heartwood and sapwood portions) of *Laguncularia racemose*

are small in relation to the range of variations in overall carbon contents. The results for organic carbon content for *L. racemosa* in this research followed the same trend with relatively small differences between sapwood and heartwood for trees from each region.

3.2 Evaluation of ash content

Figure 3 shows the mean ash content of *Laguncularia racemosa* samples from CR and WR.

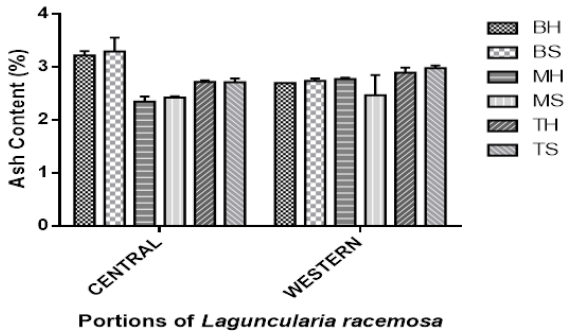

Figure 3. Mean Ash Content of *Laguncularia racemosa*

MS = Sapwood of Middle, TH = Heartwood of Top, TS = Sapwood of Top.

In Figure 3, CR samples had the highest ash content at the base sapwood (3.29%), followed by the top sapwood (2.72%) and the middle sapwood (2.42%). The heartwood was similarly higher in ash content at the base portion (3.22%), followed by the top (2.72%) and the middle (2.35%) for the same region. WR samples had the highest mean value at the top for both sapwood and heartwood (2.98 and 2.89%, sapwood and heartwood, respectively) and the least at the middle portion for sapwood (2.47%) and at the base for heartwood (2.70%). The sapwood was generally higher in ash content than heartwood except in the middle portion of samples from WR, where the heartwood was higher than the sapwood. Figure 4 shows

the mean ash content along the stem (heartwood and sapwood portions) of *Laguncularia racemose*.

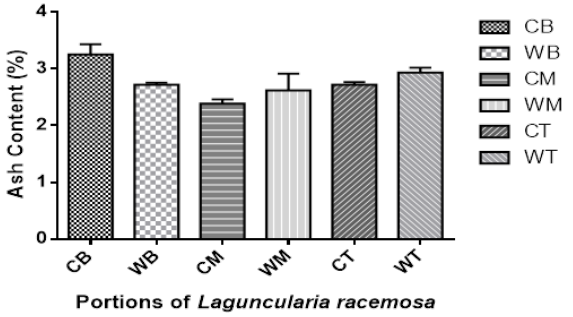

Figure 4. Mean ash content along the stem (heartwood and sapwood portions) of *Laguncularia racemose*

CB = Central Base, CM = Central Middle, CT = Central Top, WB = Western Base, WM = Western Middle, WT = Western Top.

The ash content (heartwood and sapwood) along the stem (Figure 4) indicates that ash content was highest at the base (3.26%), followed by the top (2.72%) and the middle (2.39%) for CR, while it was highest at the top (2.94%) followed by the base (2.72%) and then the middle (2.62%) for WR. Although CR recorded a generally higher ash content at the base, it was comparatively low at the middle and top portions than WR. There was a significant difference in ash content ($p < 0.05$) for the different stem portions from the two regions.

According to Imbeah (1999), ash content varies greatly within trees, being highest at the heartwood and decreasing towards the bark. From this study, the heartwood generally recorded a fairly higher ash content than the sapwood for both regions (Figure 3). The trees from CR had their base portions also recording a significantly higher ash content, whiles those from WR recorded a relatively higher ash content at the top portions (Figure 4). However, a post hoc analysis indicated nearly no significant difference between the portions from WR and the corresponding portions along the heartwood and sapwood. According to Nurfaizah et al. (2014), wood portions with higher densities result in an increase in the percentage of ash content as a result of the conversion of sapwood into heartwood from the bottom to the top portion of the tree, thus giving the bottom portion (with more heartwood and higher density) higher ash content than the top portion of the tree.

The overall mean ash content recorded was 3.26 - 2.39% for CR and 2.94 - 2.62% for WR (Figure 4). According to Ndlovu (2007), temperate-climate woods yield 0.1-1.0% ash, while tropical and sub-tropical woods yield up to 5%. Campbell (1990) also indicates that, on average, the burning of wood results in about 6 - 10% ash. The ash content of *L. racemosa* from this study is within the expected range for tropical woods. According to Kollmann (1959) and Campbell (1990), other factors that influence the amount and composition of ash include the season, weather conditions, and soil mineral availability. CR samples with a generally higher ash content suggest that the soil from which the samples were harvested might have more minerals than those from WR. Thus, *L. racemosa* wood with a relatively low ash content may be useful as biofuel for industrial applications.

3.3 Evaluation of nitrogen (N) content

Figure 5 shows the mean nitrogen content of *laguncularia racemosa* from CR and WR.

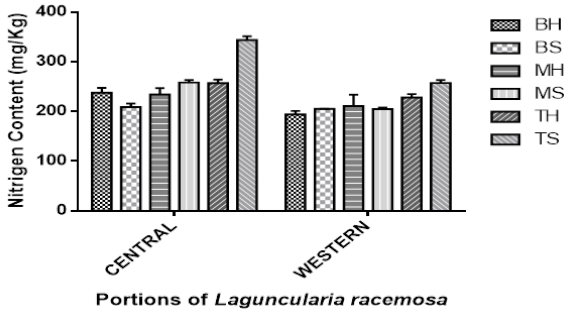

Figure 5. Mean ash content along the stem (Mean nitrogen content of *Laguncularia racemosa*

BH = Heartwood of Base, BS = Sapwood of Base, MH = Heartwood of Middle, MS = Sapwood of Middle, TH = Heartwood of Top, TS = Sapwood of Top.

Nitrogen content was high at the top for sapwood (343.81 and 257.16 mg/Kg, CR and WR, respectively) and heartwood (256.82 and 228.17 mg/Kg, CR and WR respectively) (Figure 5). However, CR samples recorded low values at the base for sapwood (237.82 mg/Kg) and middle for heartwood (234.31 mg/Kg), while WR samples recorded low values at the base (194.06 mg/Kg) for heartwood and middle for sapwood (204.90 mg/Kg) (Figure 5). Figure 6 shows the mean nitrogen content along the stem (heartwood and sapwood portions) of *Laguncularia racemose* from CR and WR.

CB = Central Base, CM = Central Middle, CT = Central Top, WB = Western Base, WM = Western Middle, WT = Western Top.

From Figure 6, nitrogen content was generally high for CR, increasing from base to top along the stem (223.41 – 300.32 mg/Kg) compared to WR (199.55 – 242.66 mg/Kg). There was no significant difference in nitrogen content except that of the base and middle portions of samples from WR. The combined nitrogen content (sapwood and heartwood) for *L. racemosa* ranged from 223.41 – 300.32 mg/Kg for CR and 199.55 – 242.66 mg/Kg for WR. According to Meier et al. (2013), when wood is burned for fuel, nitrogen oxide (NO_2) may be formed through the

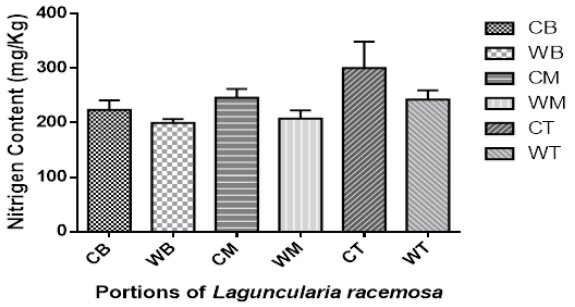

Figure 6. Mean nitrogen content along the stem (combined heartwood and sapwood portions) of *Laguncularia racemose*

oxidation of nitrogen in the wood. Mitchual et al. (2014) indicated that levels of NOx could be beneficial since they enrich forest soil. Thus *L. racemosa*, from WR, with relatively low nitrogen content, is recommended for use as wood fuel since the amount of nitrogen oxides emission from its combustion can be relatively low. However, negative impact on health from the emission of high levels of NOx, including acidification of water and soils (Mitchual et al., 2014) and the risk of respiratory infections (Sillman, 2003), has been reported. Sillman (2003) also indicated that photochemical smog could be formed when NOx reacts with volatile organic compounds in the presence of sunlight and thus pollute the air. Since the sapwood generally recorded relatively high nitrogen content and the distribution along the stem largely increased from base to top (Figure 5), the sapwood and towards the top portions of *L. racemosa* may have the potential to pollute the environment and could have negative health effect when used as fuel. The values of nitrogen content recorded from this study are, however, lower than what was reported by Mitchual et al. (2014) for *A. robusta*(481.3 mg/Kg), *C. pentandra* (481.7 mg/Kg) and T. scleroxylon (560.0 mg/Kg). The results from both regions were below the recommended levels (Nitrogen content $\leq 0.3\%$) set by the Austria national standard for pellets and briquettes, Austria ÖNORM M7135 (Mitchual et al., 2014). It is also below the German national standard for fuel pellets, except for the sapwood of the top portion for CR, Germany DIN 51731 /DINplus (Mitchual et al., 2014). This further confirms that *L. racemosa*, especially those from WR, may be ideal for use as wood fuel because of the relatively low nitrogen content.

4. Conclusion

The organic carbon, ash, and inorganic mineral elements composition of *L. racemosa* make it suitable as a biofuel energy source for industrial purposes. *L. racemosa*, from WR, has a relatively low nitrogen content compared to CR. It may be recommended for wood fuel since the amount of nitrogen oxide emission from its combustion can be relatively low. The sapwood generally recorded relatively higher nitrogen content from *L. racemosa*.

References

[1] American Society for Testing and Materials (ASTM) D1102-84 (2007). Standard Test Method for Ash in Wood.

[2] Bremner, J. M., & Mulvaney, C.S. (1982). Nitrogen – Total. In A. L. Page, R.H. Miller and D.R. Keeney (eds.). Methods of soil analysis. Part 2, Agronomy 9, 595-624.

[3] Campbell, A. G. (1990). Recycling and disposing of wood ash. Department of Forestry, University of Idaho, Mosco, TAPPI journal, 73 (9):141 –14 6 Chapman and Hall, N.Y. London.

[4] Heanes, D. L. (1984). Determination of total organic carbon in soils by improved chromic acid digestion and spectrophotometric procedure. Communications in Soil Science and plant analysis 15: 1191-1213.

[5] Imbeah, M. (1999). Wood ash is a mineral supplement for growing lambs under village conditions in the tropics. 32 (2) 191-194. https://doi.org/10.106/s0921-4488(98)00181

[6] Kollmann, F. (1959): Wood technology and applications. (Tecnología de la Madera y sus Aplicaciones). Ministerio de Agricultura. Instituto Forestal de Investigaciones y experiencias, Madrid (in Spanish).

[7] Matthews, G. (1993). The Carbon Content of Trees, Forestry Commission Technical paper 4 Forestry Commission, Edinburgh, 1-21

[8] Meier, S. R., Rector, G., Allen, P. K., Hopke, S. R., & Chandrasekaran, L. L. (2013). Elemental Analysis of Wood Fuels, New York State Energy Research and Development Authority (NYSERDA) Albany, New York, 1-46.

[9] Mitchual, S. J., Frimpong-Mensah, K., & Darkwa, N. A. (2014). Evaluation of Fuel Properties of Six Tropical Hardwood Timber Species for Briquettes. World Academy of Science, Engineering and Technology. International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol: 8, No: 7, [International Scholarly and Scientific Research & Innovation 8(7)

[10] Ndlovu, H. (2007). Ash from homestead fireplaces and wood as possible sources of minerals for livestock. Nematology, Florida Cooperative Extension Service, Institute of Food and Agricultural.

[11] Nelson, D.W., & Sommers, L.E. (1982). Total carbon and organic matter. In: Page, A.L., Miller, R. H., & Keeney, D.R. (eds.): Methods of soil analysis

Part 2, 2nd ed. No.9. American Society of Agronomy. Soil Science of America,Madison, 595 – 579, Wisconsin, USA.

[12] Nurfaizah, A. L., Nur S. M. T., & Jamaludin, K. (2014). Physical and Chemical properties of kelempayan (neolamarckia cadamba sp.), wood International Journal of Latest Research in Science and Technology. 3, (6): 215-219

[13] Sillman, S. (2003). "Tropospheric ozone and photochemical smog, in B. Sherwood Lollar, ed., Treatise on Geochemistry, Environmental Geochemistry, Ch. 11, Elsevier, Vol. 9 http://www.TreatiseOnGeochemistry.com

[14] Spalding, M., Kainuma, M., & Collins, L. (2010a). World Atlas of Mangroves. A collaborative project of ITTO, ISME, FAO, UNEP-WCMC, UNESCO-MAB, UNU- INWEH and TNC. London (UK): Earthscan, London. 319 pp. Data layer from the World Atlas of Mangroves. In Supplement to Spalding et al. Cambridge (UK): UNEP World Conservation Monitoring Centre. URL: data.unep-wcmc.org/datasets/22.