DETERMINATION OF THE PHYSICAL AND CHEMICAL COMPOSITIONS OF CHARCOAL SAMPLES USED FOR EXPLOSIVE PRODUCTION

By

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ABSTRACT

A study of the physical and Chemical Compositions of charcoal samples of five selected Nigerian tropical plant materials, commonly used for explosive (black powder) production, had been carried out. The tropical plant materials, which were obtained at seven different locations are teak (tectona grandis), cassava (manihot esculentas), bamboo (bambusa spp), pigeon pea (cajanus cajan) and charcoal tree (trema orientalis). The analyses of variance (ANOVA) carried out at 0.05% level of significant shows that the charcoal samples of the five tropical plant materials obtained within the same location were different from each other. However, at 0.05% level of significant, there was no significant difference between the same sample at difference locations. Consequently, not all plant materials would provide the same charcoal (C) requirement in the production of black powder while the same plant specie would provide the same type of charcoal (C) requirement regardless of their locations.

Key words: *quality, explosive, composition, charcoal, production,, significant, location.*

1.0 INTRODUCTION

The fact that charcoal (C) is one of the principal ingredients for the production of low explosives called black powder (BP) is not in doubt. The major problem has been the choice of plants that would yield the right 'C' for the production of good quality BP. Black powder belongs to the low explosive categories and is a mixture of charcoal, saltpeter (potassium nitrate) and sulphur. The charcoal can be made from virtually any organic material, like wood straw, rice husks and bones. For the production of charcoal for domestic fuel, usually the hardwood species are preferred. These include acacia, mangroves, oak, ekki, danta, afzella, afromesia and "iroko" (Bhattarai, 1998). Coconut shells and crop residues are also been used at substantial scale. However, for the production of fireworks and black powder, specialist charcoals with specific burning properties such as that made from willow or grapevine are required (Gill, 2002).

Charcoal is cleaner, easier and less smoky than other biomass fuels. It can be used in smaller quantities with cheap burning devices for domestic applications. These burning properties are also useful in black powder production (Foley, 1986). Commercial charcoal is produced in kilns by a process called pyrolysis i.e. breaking down the chemical structure of wood under high temperature in the absence of air. During the process, first the water is driven from the wood (drying) and then pyrolysis starts when the temperature in the kiln is high enough.

Industrial applications of charcoal included incense sticks, extraction of calcium carbonate from limestone and manufacturing of black powder, which is the focus of this paper. Black powder is a form of explosive that is low in explosive strength and is in high demand by dimensional stone quarries. This is because of its ability to deflagrate or burn instead of detonating. This unique characteristic allows it to separate a large block of granite, shale, limestone and marble from the host rock without causing damage or cracks after blasting. It therefore follows that the charcoal to be used for black powder production should be of the right quality physically and chemically. Opafunso (2003) reported, in his study of selected tropical plant materials as sources of charcoal (carbon) for the production of explosive, that the BP of *trema orientalis* shows a greater promise (than detonating cord) for use for blasting purposes in dimensional stone quarries. The study also revealed that the BP of manihot *esculentas* would do well for use as gunpowder for sporting purposes while that of *cajanus cajan* would be an ideal ingredient for the making of fireworks and Christmas "bisco" light.

The discovery of black powder has all along being a subject of controversy. While some known author traced its discovery to China, others traced it to the Middle East. According to the New Standard Encyclopedia (2002), black powder was known in China as early as the 10^{th} century and probably first used in Europe in firearms during the 14^{th} century. The use of black powder in blasting for mining and construction began in the 17^{th} century. Until the middle of 19^{th} century, when Nitrocellulose (gun cotton) and other explosives were invented, black powder was the only practical explosive available. Nitroglycerine was invented in 1847 but was too dangerous for practical use, until Afred Nobel, a Swedish Chemist, invented dynamite in 1886 (Nobel, 1886).

Since BP had been and is still being used as gunpowder and blasting agents, it is necessary to understand the role charcoal play in its production by reviewing two current methods of preparing black powder. The methods are ball mill method (Bacon (2001) and Precipitation method (Opafunso, 2003).

1.1 The Ball Mill Method

(1) Crush raw charcoal with a hammer between two sheets of paper. Wear old clothing and do this outside, since it is very messy. Sieve the charcoal using a coarse sieve (about 30 mesh).

(2) Weigh the charcoal. To every 5kg of charcoal, add 3.5 kg of sulphur, and fill one-quarter of your ball mill with the mixture. Put the mixture/media in and let the mill run for 3 hours.

(3) When you open your mill, you should found an incredibly fine black/greyish powder. Remove, sieve and weigh the powder. Next, place 4kg of potassium nitrate in your ball mill and run for 3 hours. You should have a very fine white/greyish powder.

(4) Now mix the charcoal/suphur powder with the potassium nitrate powder. Don't bother to mix it very thoroughly, since that will happen in the mill. Spray 2.5 litres of water over the powder mixture for every 5kg of mixture media. Then spread it out on a sheet of paper to make sure all of it becomes wet. Put the wet powder in your mill and run for 5 hours. Every hour or so, check to see if the powder is still wet. If it dries out completely, the risk of accidental explosion/ignition greatly increases.

(5) Sieve the powder to get the media out, spread it out on a large sheet of paper and let it dry. If possible in the sun. Needless to say you shouldn't heat it order to dry it more quickly, just be patient.

(6) When dry, sieve the black powder through sieves of different sizes to get several fractions for different purposes.

1.2 The Precipitation Method

(7) Crush raw charcoal with a hammer between two sheets of paper. Wear old clothing and do this outside, since it is very messy. Sieve the charcoal using a coarse sieve (about 30 mesh).

(1) Weigh the charcoal. To every 5kg of charcoal, add 3.5kg of sulphur, and fill one-quarter of your ball mill with this mixture.

Put the mixture/media in and let the mill run for 8 hours.

(2) Meanwhile, while the mill is running, place 3 litres isopropyl alcohol in large container for every 5 kg of charcoal/sulphur mix you have, and place in a fridge.

(3) When you open your mill you should find an incredibly fine black/greyish powder. Sieve this to get the mixture/media of the mill out, and weigh it. In a separate container, place 4 kg of potassium nitrate for every 4 kg of charcoal sulpur powder you have. Put the potassium nitrate in an old pan, and add 2 litres tap water for every 5 kg of potassium nitrate.

(4) Place the pan on the stove and bring it to a boil while continuously stirring. When the solution starts to boil, add small amounts of water while stirring all the time until all the potassium nitrate has dissolved.

(5) Add an extra 1litre tap water and the charcoal/sulphur mixture to the boiling potassium nitrate solution - stir the charcoal/sulphur mixture in the solution. Make sure there are no dry clumps left.

(6) By now, your isopropyl alcohol should have cooled to at least 0^oC or colder. Take the isopropyl alcohol outside, and pour the potassium nitrate solution/ charcoal/sulphur into the cold isopropyl alcohol. Make sure there are no sources of ignition nearby! Cool the mixture again to 0^oC at the fastest rate you can. The faster the better.

(7) Stir the mixture for few seconds and filter through a clean white cloth. Squeeze to get all the black liquid out and discard.

(8) Spread the black mixture on a sheet of paper, and dry it in the sun. Don't try to dry it inside since it will produce a lot of flammable vapour from the isopropyl alcohol. When it is still slightly wet to be touch, press through a sieve to corn it. Then dry it further.

(9) When dry, sieve the black powder through sieves of different sizes to get several fractions for different purposes.

It should be noted that the two methods are quite ideal for black powder production. However, each have it's own advantages and disadvantages. Advantage of the ball mill method is that it is less laborious, as you can simply charge your mill with the ingredients, turn it on, do something else for a couple of hours and you are done. It's main disadvantage is that it is essential that you have a safe place for the milling process.. A place with no buildings, people or animal whatsoever in the neighbourhood, and you should be able to turn it on and off remotely. It also makes a lot of noise. With the precipitation method, more work is carried out when you will first mill the charcoal and sulphur together. This is similar to the ball mill method where the charcoal and sulphur are first milled together); but this is followed by dissolving the potassium nitrate in hot boiling water which is then mixed with the milled charcoal/sulphur mixture. The potassium nitrate is then precipitated from the solution by mixing with ice cold isopropyl alcohol. This is followed by filtering and drying. This takes a long time. Also, a good location with no ignition sources is required, since a flammable liquid evolves during production.

World Book Encyclopedia (2002) explains that black powder was the first explosive that we know anything about. Theoretical knowledge shows that it is made up of potassium nitrate (KNO_3), charcoal (C) and sulphur (S). Since Potassium Nitrate and Sulphur are available in the market, and charcoal is the third ingredient needed for the production of black powder, it is desirable to find out if charcoal from different tree/plants produce the right "C" for charcoal production.

The objective of the study was to determine the quality of the charcoal samples of selected Nigerian tropical plant materials commonly used for black powder production. This was done through the evaluation of the physical and chemical characteristics of selected charcoal samples commonly used as raw material for the production of black powder explosive.

2.0 MATERIALS AND METHOD

Samples of mature tropical plant materials namely: Teak (*tectona grandis*), cassava, (*manihot esculentas*), bamboo (*bambusa spp*), pigeon pea (*cajanus cajan*) and charcoal tree (*trema orientalis*) were obtained from seven different locations in Nigeria and used to produce charcoal samples in a furnace at 400^0C. The locations are Akure, Ado–Ekiti, Oshogbo, Ibadan, Abeokuta, Kaduna and Asaba.

The moisture content and specific gravity of the charcoal samples were determined using American Society for Testing and Materials (ASTM) D 143-52, (1999) procedures. The hardness of the charcoal samples were determined using American Society for Testing and Materials (ASTM) D2013-72 (1999) standard method of preparing coal samples for analysis. The proximate analysis of the charcoal samples was carried out using standard methods for coal and coke analyses of American Society for Testing and Materials (ASTM) D1102-84, (1999) procedures to determine the volatile matter, ash content and the carbon content of the charcoal samples. Figures 1 to 6 shows the moisture content, specific gravity, hardness, volatile matter, ash content and carbon content of the charcoal samples from the seven locations. The data obtained were subjected to analyses of variance to test whether there is significant difference between the moisture content, specific gravity, hardness, ash content, volatile matter and carbon content of charcoal samples at the seven different locations on one hand and at the same locations on the other hand.

3.0 RESULTS AND DISCUSSION

Figure 1 shows that the moisture content of the charcoal samples averages between 12.91% for *manihot esculentas* and 16.43% for *tectona grandis*. Others are 13.29%, 15.57% and 15.70% for *cajanus cajan*, *trema orientalis* and *bambusa spp* respectively. The specific gravity of the analyzed charcoal samples, which are shown in Figure 2 are: 0.73, 0.79, 0.87, 1.08 and 1.19 for *tectona grandis*, *manihot esculentas*, *trema orientalis*, *cajanus cajan* and *bambusa spp respectively*. Figure 3 shows that the charcoal samples of *tectona grandis* and *trema orientalis* had the highest hardness of 1.21 and 1.11 respectively. *Bambusa spp* and *cajanus cajan* had hardness value of 0.99 each while the hardness value of *manihot esculentas* was 0.97. Figure 4 gives the volatile matter of the charcoal samples to be 4.17, 4.40, 4.50, 8.30 and 9.50 for *manihot esculentas*, *trema orientalis*, *cajanus cajan*, *bambusa spp* and *tectona grandis* respectively. The ash contents of the charcoal samples are shown in Figure 5 with *manihot esculentas* and *cajanus cajan* having the highest ash content of 29.42% and 21.14% respectively. The ash contents for the others are 19.14%, 14.0% and 6% for *bambusa spp*, *trema orientalis* and *tectona grandis* respectively. The carbon content of the charcoal samples are shown in Figure 6 to be 66.90%, 72.36%, 74.57%, 81.70% and 84.50% for *manihot esculentas*, *bambusa spp*, *cajanus cajan*, *trema orientalis* and *tectona grandis* respectively.

The results of the physical and chemical analyses were subjected to analysis of variance (ANOVA) tests as follows:

3.1 Test of Hypothesis (1) - Analyses of Variance based on the same Charcoal Samples at different Locations.

Hypothesis 1: Testing whether there is significant difference between the moisture content, specific gravity, hardness, ash content, volatile matter and carbon content of charcoal samples at the seven different locations.

Null Hypothesis; H_0: There is no significant difference between the same samples at different locations.

Alternative Hypothesis; H_1: There is significant difference between the same samples at different locations.

Table 1 shows the detail result of the ANOVA from the above test. The results show that there is no significant difference at 0.05 level of significant. The decision is that since all the figures in the last column are greater than 0.05, therefore the null hypothesis is accepted and there was no significant difference between the same samples at difference locations. In other words, the charcoal samples of *trema orientalis*, obtained from seven different locations are not different from each other in term of chemical and physical compositions. This assertion is true of other analyzed charcoal samples of *manihot esculentas*, *bambusa spp*, *cajanus cajan* and *trema orientalis*.

3.2 Test of Hypothesis (2) - Analyses of Variance based on different Charcoal Samples in the same Location.

Hypothesis 2: Testing whether there is significant difference between the charcoal samples based on the moisture content, specific gravity, hardness, ash content, volatile matter, and carbon content of the charcoal samples at the same locations.

Null Hypothesis; H_0: There is no significant difference between the charcoal samples within the same location.

Alternative Hypothesis; H_1: There is significant difference between the charcoal samples within the same location.

Table 2 shows the detail result of the ANOVA from the above test. The result shows that, at 0.05 level of significant, there is significant difference between the samples within the same location. The decision is that since all the figures in the last column are less than 0.05, therefore, the null hypothesis is rejected, as there are significant differences between the charcoal samples within the same location. In other words, the charcoal samples of *tectona grandis*, *manihot esculentas*, *bambusa spp*, pigeon pea, *cajanus cajan* and *trema orientalis* obtained within the same location were different from each others in term of chemical and physical compositions.

5.0 CONCLUSION AND RECOMMENDATIONS

Charcoal samples of five different tropical plant materials obtained from seven locations in Nigeria had been analyzed for their physical and chemical compositions. The physical characteristics determined included moisture, hardness and specific gravity while the chemical characteristics analyzed were ash, volatile matter and carbon contents. The analyses of variance (ANOVA) carried out on the obtained data, at 0.05% level of significant, shows that the charcoal samples of *tectona grandis, manihot esculentas, bambusa spp, cajanus cajan* and *trema orientalis* obtained within the same location were different from each other. However, at 0.05% level of significant, there was no significant difference between the same samples at difference locations. Therefore, not all plant materials would provide the same charcoal (C) requirement in the production of black powder while the same plant specie would provide the same type of charcoal (C) requirement regardless of their locations.

Further study should be carried out through the use of charcoal identified in this study and from other tropical plant materials for the production of black powder. The black powders from such exercise should be ranked after field tests. In area of with long tradition of charcoal use for domestic fuels and industrial applications, its commercial development can be promoted. Anywhere the use of charcoal is limited; the immediate priority should be to ensure its sustainable supply to meet at least the present level of demand. This can be achieved through more efficient production and utilization by introducing technological innovations as well as by managing depleted natural forests for fuel wood supply besides other purposes. However, no matter how difficult it may be to visualize the future supply and demand scenario of charcoal, experience from the past suggests that the use of charcoal for black powder production and biomass fuels will not decline and may be increasing in most countries. The only exception may likely be in oil producing countries like Nigeria where people have climbed the "fuel ladder" because of cheap petroleum products. However, with the deregulation of the petroleum sector, the price of the kerosene and LPG will soon be out of the reach of the poor, thus sending them a step back in the fuel ladder. The promotion of charcoal for activities likes production of black powder for blasting purpose, and as a source of alternative cheap energy will ensure it's continue relevant in Nigeria.

Production and usage of charcoal and other wood fuels are currently not been regulated all over the world, including Nigeria. It can be said to fall between organizational cracks. Currently, there is a very little co-ordination and collaboration between Energy and Agriculture Ministries in various countries. This is partly because Energy ministries are more concerned with electrification and the supplies of petroleum products and Ministry of Forestry /Agriculture is more concerned with the production of timber in forest reserves and conservation of wood resources in natural forests. In general, developing countries like Nigeria lack the organizational capacity to formulate effective regulations for wood fuel and charcoal utilization. Arbitrary interventions or non-interventions in the wood fuel sector have resulted neither in effective regulation nor in the control of the sector. Currently in Nigeria only the Nigerian Police regulate the granting of license for the production and usage of black powder.

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TABLE 1: RESULT OF ANOVA TEST TO DETERMINE SIGNIFICANT DIFFERENT BETWEEN THE SAME SAMPLES AT DIFFERENT LOCATIONS

Source of Variation (SV)		Sum of Square (ss)	Degree of Freedom (df)	Mean Square (ms)	F(cal)	Sig.
Moisture Content	Between Group	2.12	5	0.35	0.120	0.99*
	Error	82.75	24	2.96		
Specific Gravity	Between Group	3.14 x 10-4	5	5.25 x 10-5	0.001	1.00*
	Error	1.07	24	3.82 x 10 - 2		
Hardness	Between Group	1.27 x 10-3	5	2.11 x 10– 4	0.021	1.00*
	Error	283	24	1.01 x 10-2		
Ash Content	Between Group	16.00	5	2.67	0. 037	1.00*
	Error	2035	24	72.70		
Volatile Matter	Between Group	0.16	5	2.66 x 10– 2	0.004	1.00*
	Error	181.01	24	6.47		
Carbon Content	Between Group	13.95	5	2.32	0.047	1.00*
	Error	1391.17	24	49.69		

- There is no significant difference at 0.05 level of significant.

TABLE 2: RESULT OF ANOVA TEST TO DETERMINE SIGNIFICANT DIFFERENCE BETWEEN THE CHARCOAL SAMPLES WITHIN THE SAME LOCATION

Source of Variation (SV)		Sum of Square (ss)	Degreeof Freedom (df)	Mean of Square (ms)	F(cal)	Sig.
Moisture Content	Between Group	69.3	4	17.33	33.45	0.00*
	Error	15.55	25	0.52		
Specific Gravity	Between Group	1.07	4	0.27	4598.53	0.00*
	Error	1.7 x 10-3	25	5.8 x 10-5		
Hardness	Between Group	0.28	4	7.05 x 10-2	850.81	0.00*
	Error	2.4 x 10-3	25	8.29 x 10-5		
Ash Content	Between Group	2015.89	4	503.97	423.34	0.00*
	Error	35.71	25	1.19		
Volatile Matter	Between Group	180.70	4	45.18	2874.77	0.00*
	Error	0.47	25	1.57 x 10-2		
Carbon Content	Between Group	1372.15	4	343.04	312.10	0.00*
	Error	32.97	25	1.10		

- There is significant difference at 0.05 level of significant.

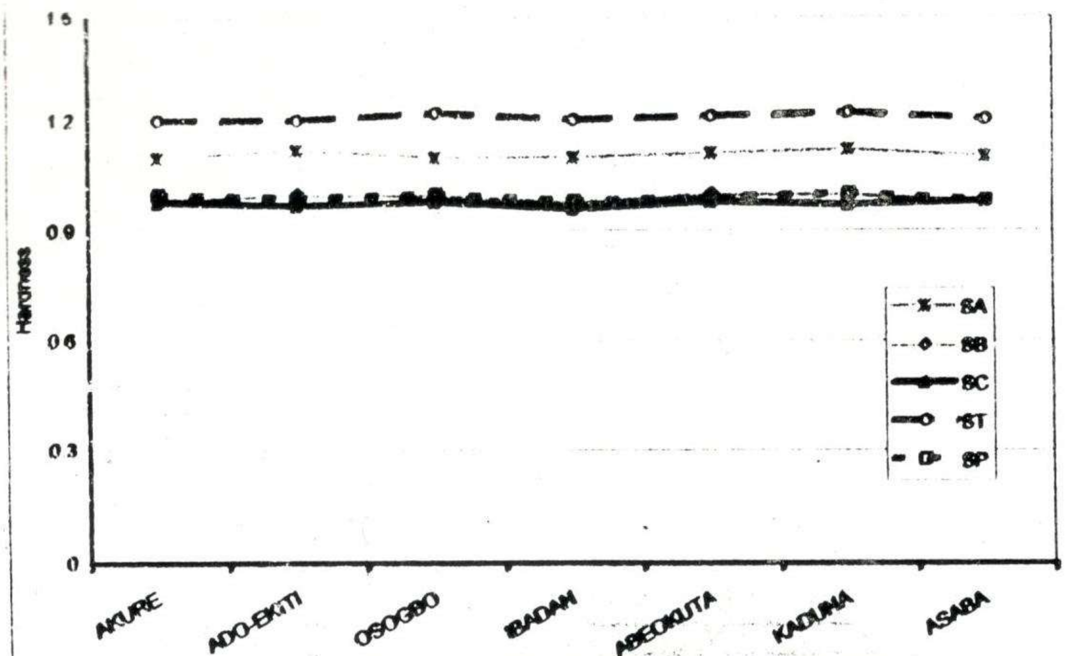


Fig 3: Summary of Hardness of Charcoal Samples of Trema Orientalis (SA), Bambusea sap(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations

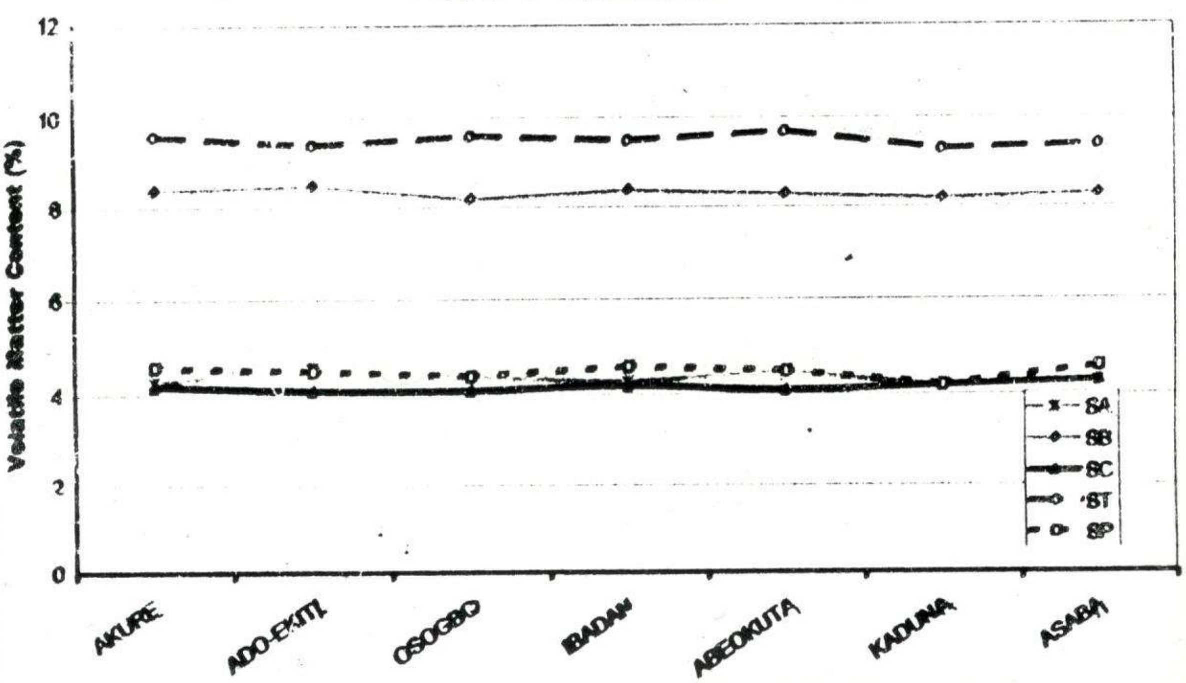


Fig 4: Summary of Volatile Matter Content of Charcoal Samples of Trema Orientalis (SA), Bambusae sap(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations

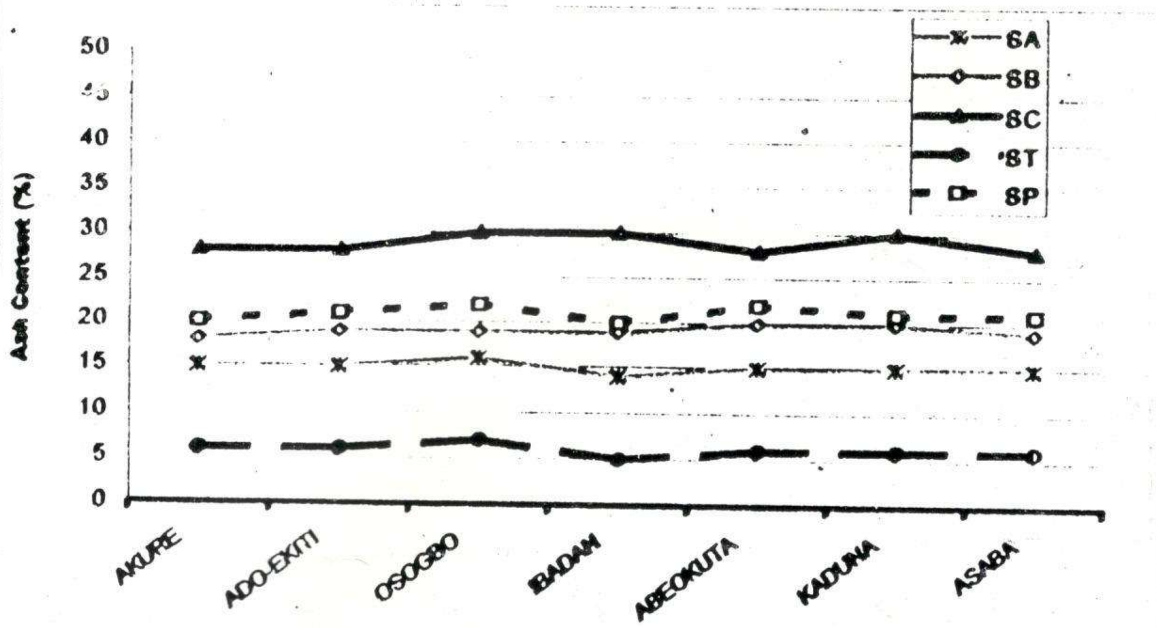


Fig 5: Summary of Ash Content of Charcoal Samples of Trema Orientalis (SA), Bambussa ssp(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations

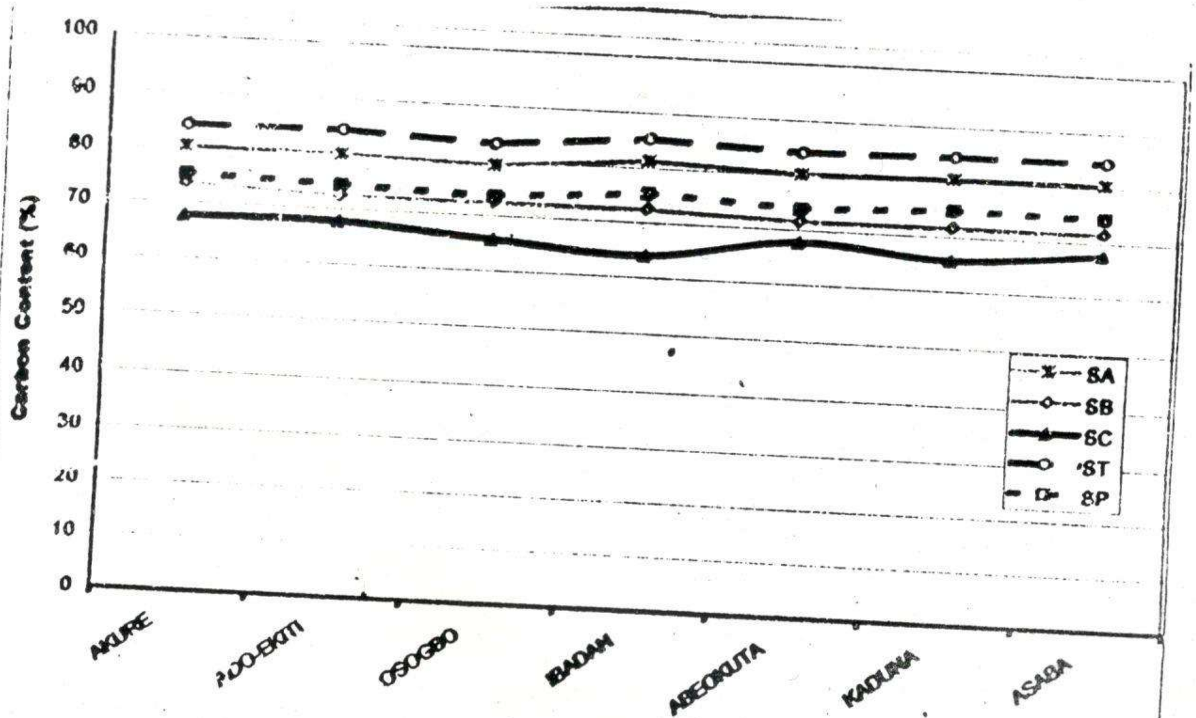


Fig 6:Summary of Carbon content Charcoal Samples of Trema Orientalis (SA), Bambussa ssp(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations

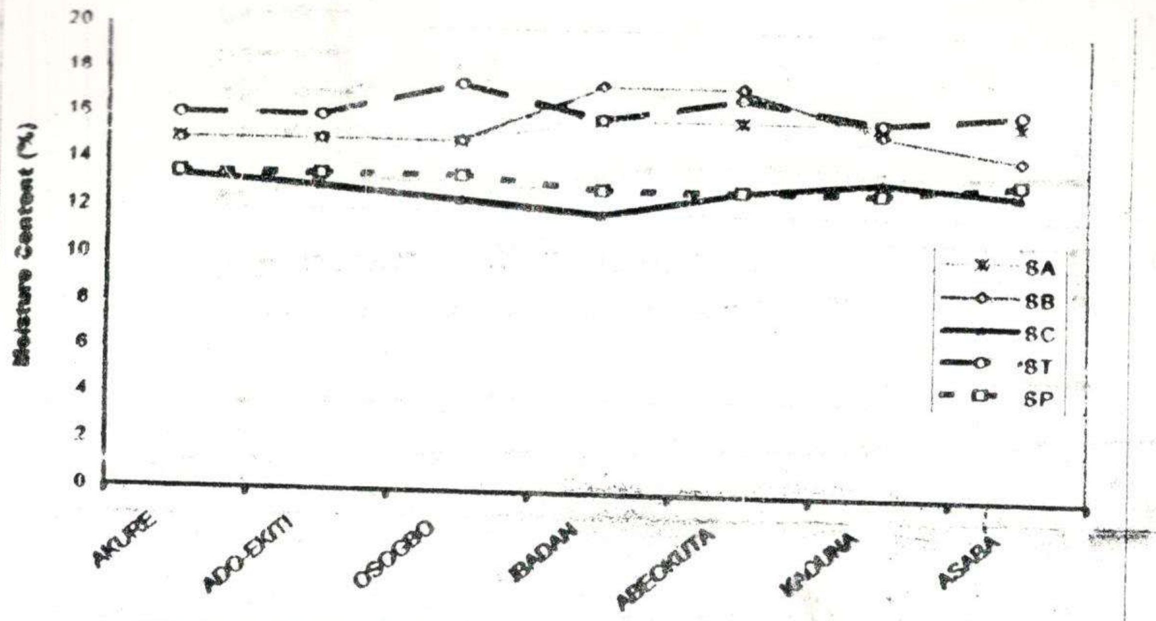


FIG 1: Summary of the Moisture Content of Charcoal Samples of Trema Orientaliet (SA), Bambusa spp(SB), Manihot Esculentas(SC), Tectona Grandis(ST), and Cajanus Cajan(SP), Obtained at the Seven locations

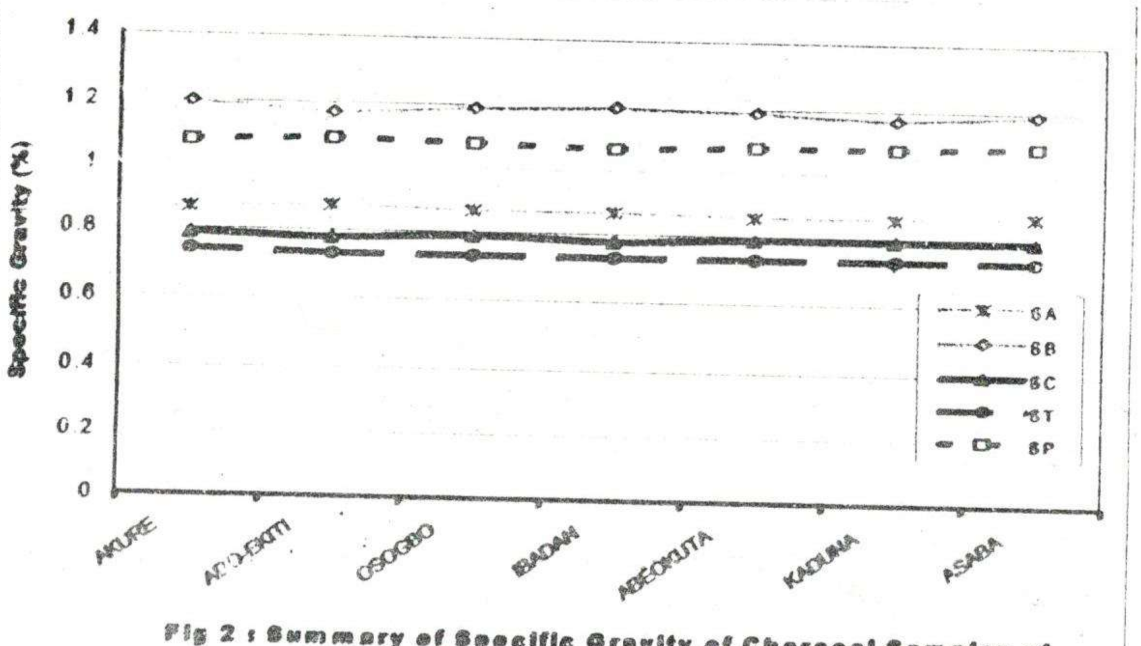
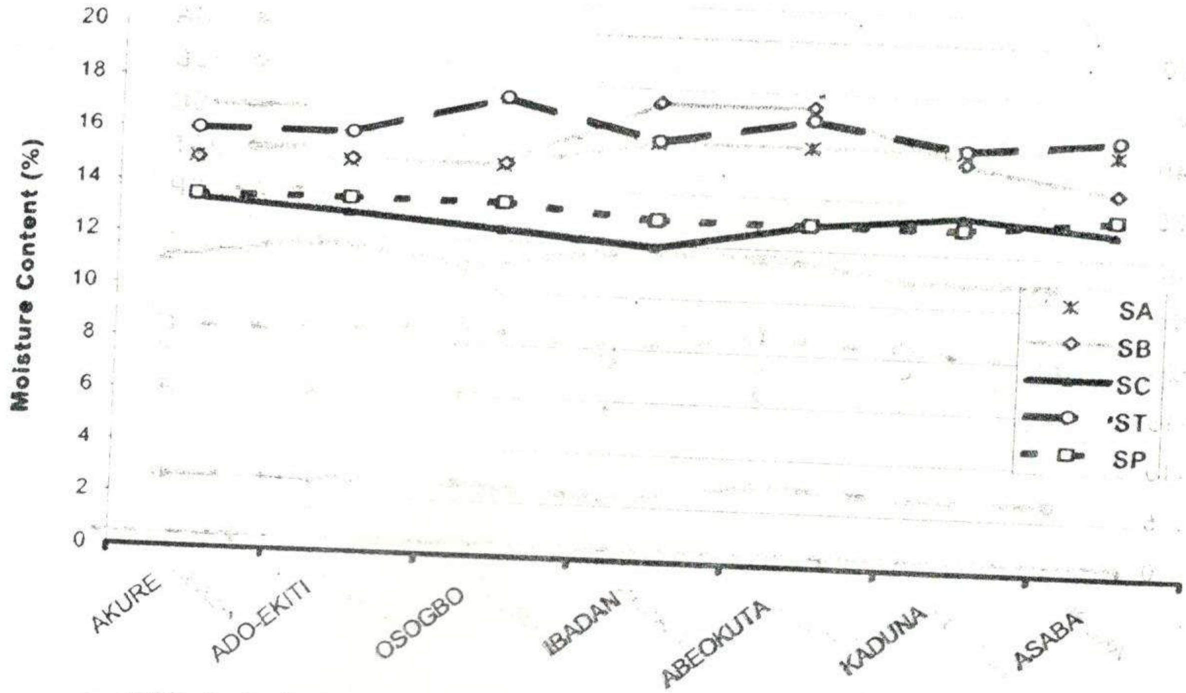


Fig 2 : Summary of Specific Gravity of Charcoal Samples of Trema Orientalis (SA), Bambusa ssp(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations



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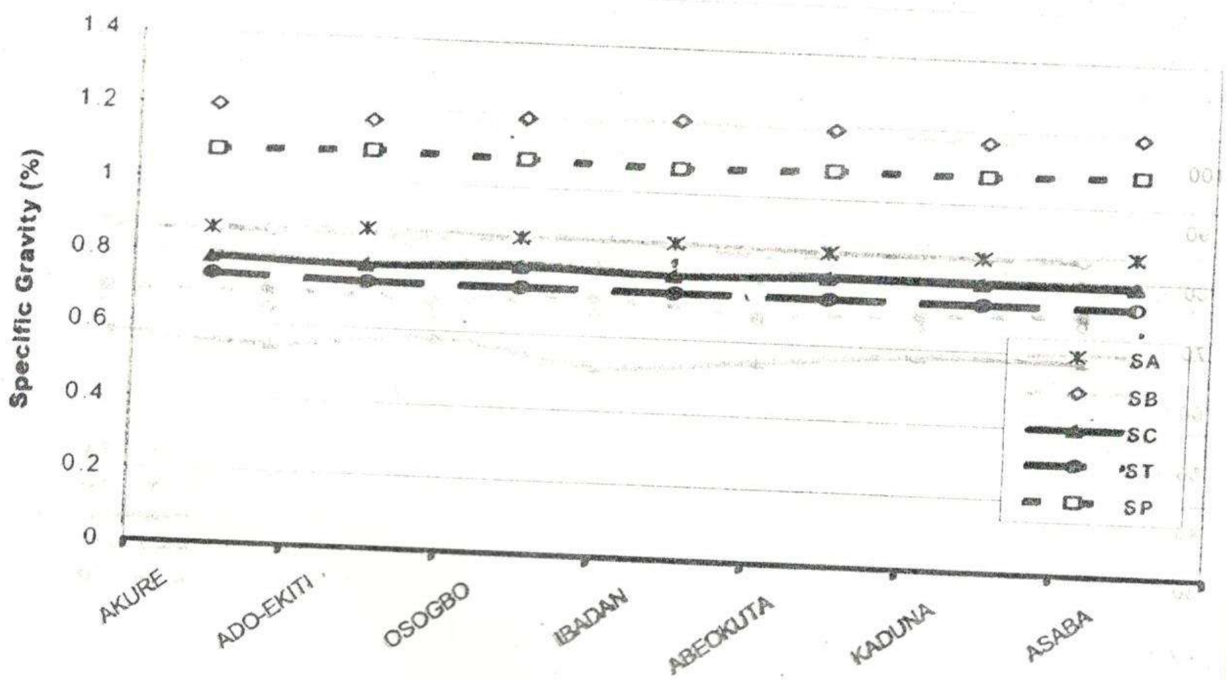

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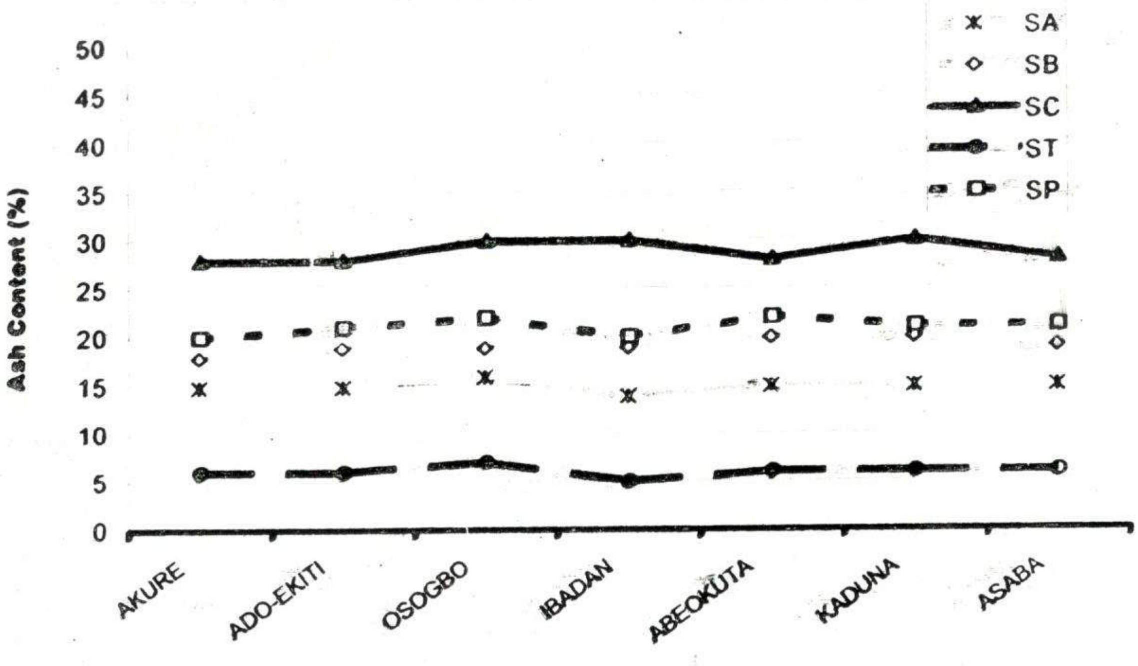

Fig 5: Summary of Ash Content of Charcoal Samples of Trema Orientalis (SA), Bambussa ssp(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations

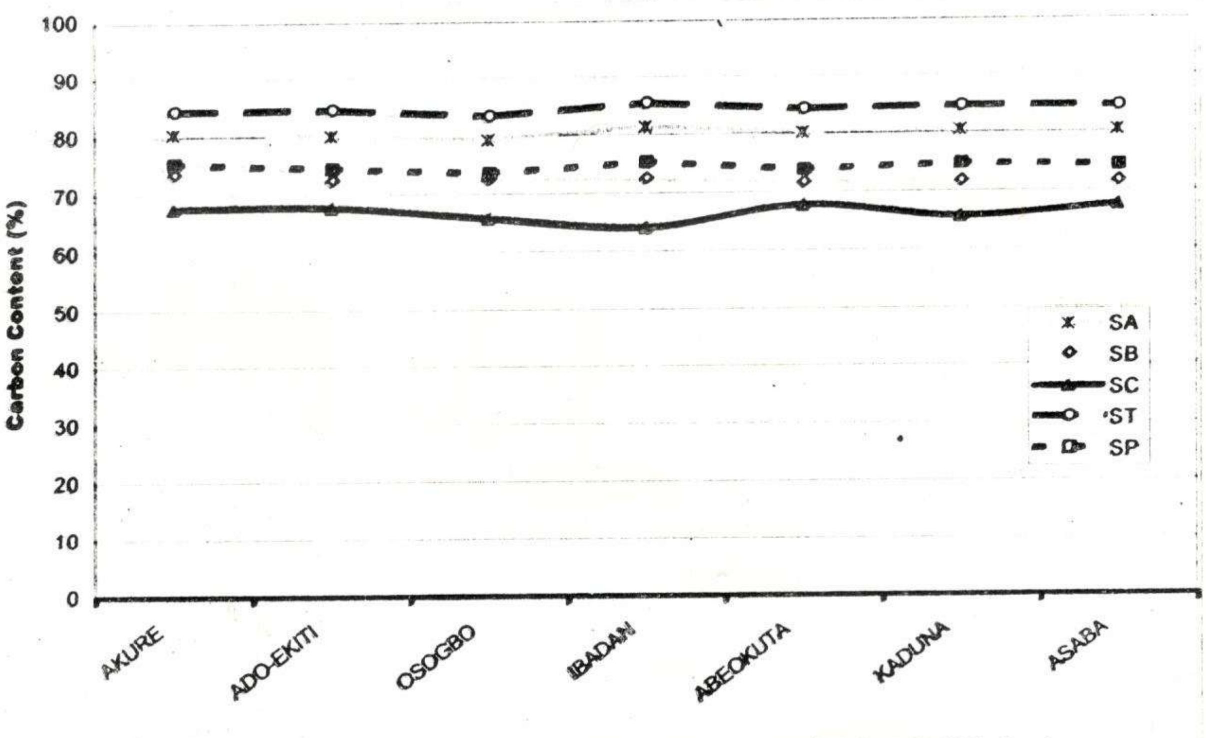

Fig 6:Summary of Carbon content Charcoal Samples of Trema Orientalis (SA), Bambussa ssp(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations

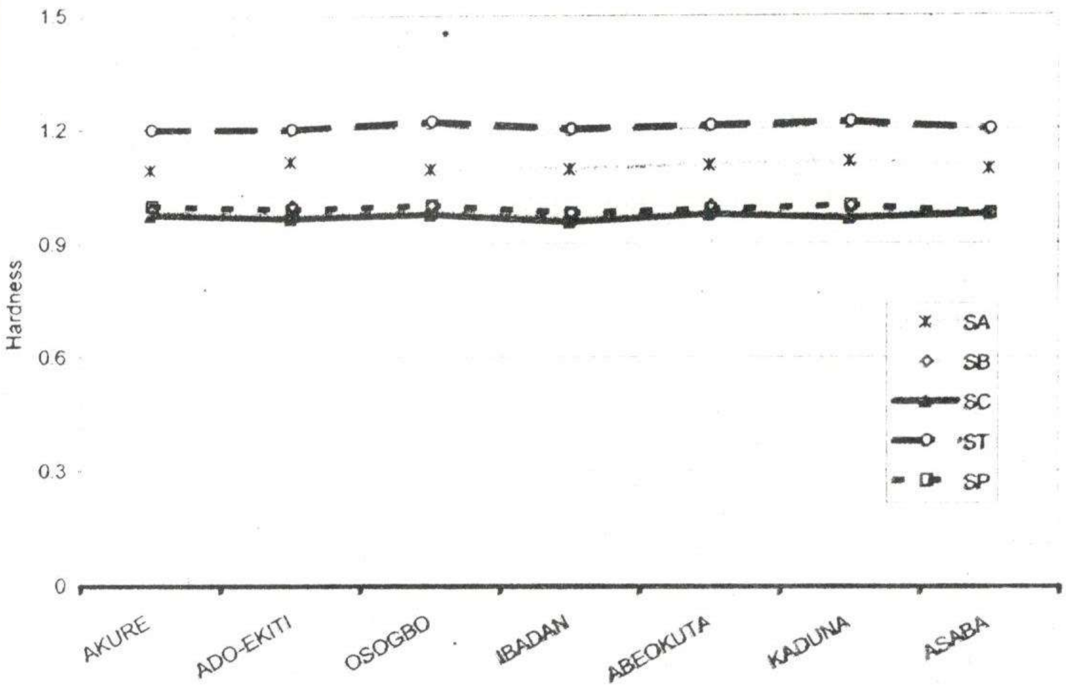

Fig 3: Summary of Hardness of Charcoal Samples of Trema Orientalis (SA), Bambussa ssp(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations

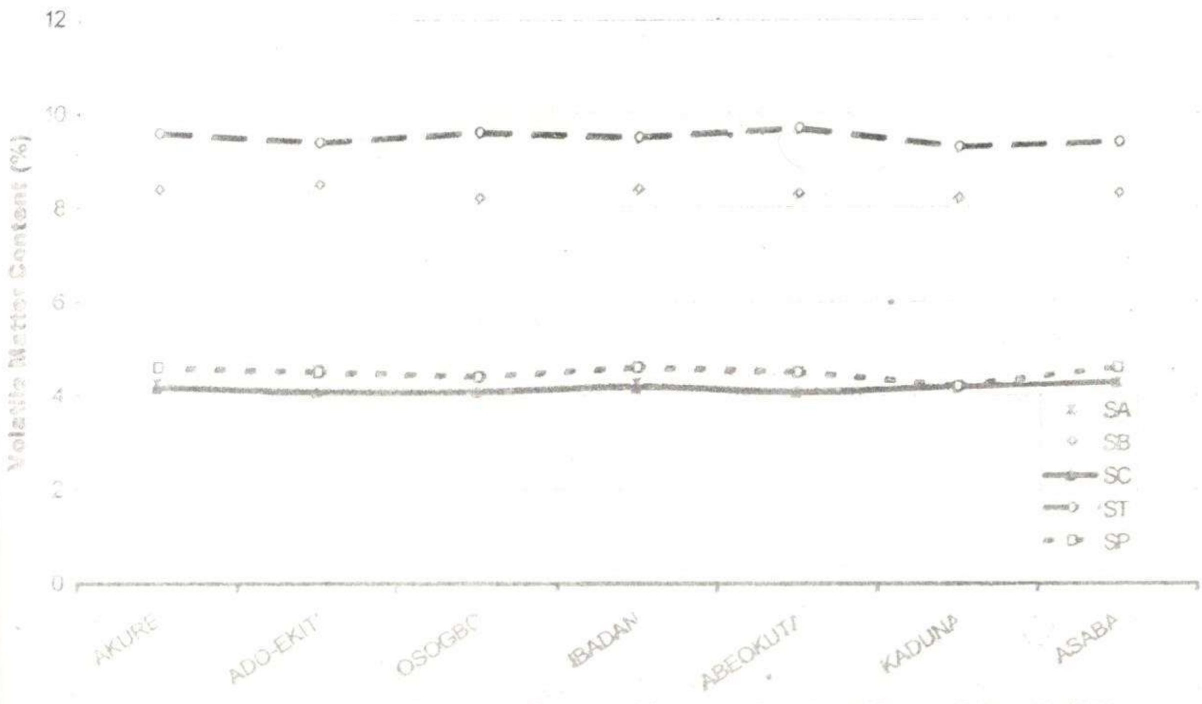

Fig 4: Summary of Volatile Matter Content of Charcoal Samples of Trema Orientalis (SA), Bambussa ssp(SB), Manihot Esculental (SC), Tectona Grandis (ST) and Cajanus Cajan (SP) obtained at the seven locations