Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.4, No.2, 2014

Carbohydrate Distribution of Particle Size Fractions of Soils in Relation to Land-use Types in Mbaise, Southeastern Nigeria

B.U.Uzoho * , G.U.Igbojionu
Dept of Soil Science and Technology, Federal University of Technology, Owerri
*Email of corresponding author: betheluzoho@yahoo.com
ginikachiuchechi@yahoo.com

Abstract
Carbohydrate content of soil particle size fractions provides useful information about soil's capacity for carbon sequestration. Carbohydrate distribution of particle size fractions of soils of cassava, fallow, bare soil and oil palm land use types in Mbaise, Southeastern Nigeria was evaluated using hydrolysis procedures involving concentrated H_2S0_4, dilute H_2S0_4, hot and cold water. Also relationships between extractable carbohydrates by the different reagents, carbohydrate contents of the bulk soil and the soil particle size fractions and that between the bulk soil and soil properties were determined. Top and sub soil carbohydrate contents of the various land uses differed (LSD 0.05), with concentrations varying in increasing order of cold water < hot water < dilute H_2S0_4 < concentrated H_2S0_4. Whereas, the sand fraction was enriched with and contained the largest concentration of water soluble carbohydrate, the clay fraction was more enriched and dominated the other extractable carbohydrate forms (conc. H_2S0_4, dil. H_2S0_4 and hot water soluble). Besides concentrated H_2S0_4 extractable (total) carbohydrate that correlated distinctly ($P < 0.05$) with hot water ($r = 0.55$), relationships between extractable carbohydrates by the other reagents were not significant. Bulk soil carbohydrate contents were closely related to the silt (0.90) and sand (0.77) than the clay (0.42) particle size fractions as indicated by the slopes of the regression equations. Carbohydrate concentrations of the sand, clay and silt fractions accounted for 69, 58 and 47% respectively of that in the bulk soil. Soil extractable carbohydrates correlated with different soil properties. The high carbohydrate concentrations and enrichment of the soil clay fractions indicated that much of the carbohydrates existed in the stable forms and not easily accessible for microbial degradation.
Keywords: Carbohydrate, Particle size fraction, Soils, Land use and Southeastern Nigeria.

1.0 Introduction

Soil organic matter (SOM) consists of two main pools; the labile or non humic and the non labile or humified organic fractions. Carbohydrate constitutes an important component of the labile fraction that represents about 5-25% of SOM (Stevenson, 1994). Its fate in soils varies depending on the SOM dynamics and transformation processes, especially decomposition, mineralization and immobilization (Zhang et al., 1999). Carbohydrate plays fundamental roles which includes; conservation of soil physical properties (Tisdall and Oades, 1982), stabilization of soil aggregates (Piccolo, 1996) and sustenance of soil microbial activities through provision of readily available energy (Insam, 1996).

Land use types and management practices affect soil carbohydrate contents. It has been noted that due to its labile nature, carbohydrate is most readily affected by land use practices than the more stable and recalcitrant humified fractions (Piccolo, 1996). Also due to its rapid turnover in response to land use and soil management than soil organic carbon, the labile carbon pool has been suggested as an early and sensitive indicator of SOC changes (Ghani et al., 2003). Several studies in Nigeria and elsewhere have reported conflicting impacts of land use on both total SOM and the content of carbohydrate fractions (Arshad et al., 1990; Spaccini et al., 2001). For instance, it has been reported that upon cultivation for 40-50 years, grassland soils lost 30-50% of their original SOM (Mann, 1985) and that the composition of SOM changed as indicated by decreased carbohydrates, lignin and proteinaceous materials (Schulten et al., 1990). Also in a study of two contrasting tropical ecosystems, high SOM and carbohydrate concentrations were obtained in forested than cultivated soils (Spaccini et al., 2001). In addition, it has been noted that whereas long term tillage reduced soil carbohydrate content (Arshad et al., 1990), its concentration remained the same with untilled plots after two years of conventional tillage in an orchard in California (Roberson et al., 1991). Influence of land use on soil carbohydrate content could be related to the soil type, texture, original carbon level and quality, distribution of soil natural aggregates and climate (Mbagwu and Piccolo, 1998; Puget and Lal, 2005). Carbohydrate distribution of soils varies with the particle size fractions. Whereas, high concentrations have been reported in the sand fractions of soils (Chesire et al., 1990; Spaccini et al., 2001), reports of a chromic Luvisol of the semi-arid northern Tanzania, indicated large concentrations in the clay fraction (Solomon et al., 2000). Also, large depletion of neutral sugars and uronic acid carbohydrate components in the silt fraction has been reported for Alfisols in Australia (Oades et al., 1987), Inceptisols in Canada (Angers and Mehuys, 1990) and Inceptisols of southern Germany (Gubbenberger et al., 1994). Equally, depletion of carbohydrate in the clay fraction of tropical

Australian soils has been reported (Dalal and Henery, 1988). Discrepancy in carbohydrate distribution of soil particle size fractions has been attributed to differences in the mineralization pattern of plant derived sugars and microbial carbohydrate inputs (Gubbenberger et al., 1994). Presence of carbohydrates in precise soil particle fractions gives an indication of their potential accessibility for microbial degradation (Spaccini et al., 2001). Research indicates that higher concentration of microbially synthesized carbohydrate occurs in the finer than coarse particle size fractions (Oades et al., 1987; Dalal and Henery, 1988; Gubbenberger et al., 1994). Spaccini et al. (2001), observed that carbohydrate held in the fine or clay particle size fractions are protected from microbial degradation due to high surface area of clay and ability to adsorb soil organic matter. According to Guggenberger et al. (1994), weak adsorption of carbohydrates to silt than clay size fractions suggests that microorganisms efficiently utilize carbohydrates as a source of energy in the silt fraction.

Procedures for the estimation of soil carbohydrate content differ. Typical methods include hydrolysis procedures using cold water, hot water, dilute and concentrated acids (Stevenson, 1994). According to Gregorich et al. (1994), the amount of carbohydrates extracted increases with increasing acid concentration and temperature of hydrolysis. Cheshire (1979) noted that the use of non-specific extraction procedures such as strong acids or bases cannot differentiate between total carbohydrate and the more specific carbohydrate sub-pools while a strong correlation has been obtained between the specific fractions and the hot water extractable carbohydrate (Debosz et al., 2002). Cold water extractable carbohydrate could be associated with the most labile and microbially accessible fraction that includes the non-structural plant carbohydrates and the extracellular microbial carbohydrate, usually extracted with hot water (Haynes and Francis, 1993).

Though soil carbohydrate distribution in particle size fractions is important in carbon sequestration, there is a dearth of information on the influence of land use on carbohydrate concentration of most soils of southeastern Nigeria. The objective of this study was therefore to evaluate the distribution of carbohydrates among particle size fractions of soils of selected land use types in Mbaise, Southeastern Nigeria.

2.0 Materials and Methods

2.1 Site Description and Soil Sampling

The study sites consisted of four land use types; Oil palm, Cassava, Fallow and Bare soil land uses in Ahiazu, Mbaise local government area, Imo state, Nigeria. Mbaise lies between Latitudes 5^0 29^1 and 5^0 31^1 N and Longitudes 7^0 14^1 and 7^0 18^1 E in the humid rainforest agro-ecological zone of southeastern Nigeria. Its mean annual temperature, relative humidity and rainfall are 32^0C, 86% and 2040 mm respectively (IPEDC, 2006). The rainfall pattern is bimodal with peaks in the months of July and September and a small dry spell known as the August break in the month of August. The soil type is Typic Paleudult (Lekwa and Whiteside, 1986). The land uses were characterized as follows: The oil palm land use was a more than thirty (30) years matured oil palm plantation that has received some inorganic fertilizer applications using urea, NPK and muriate of potash (MOP). The cassava land use consists of an arable cassava farm of about a year and three months (1yr 3months) old. The fallow land use consisted of a two and half ($2^{1/2}$) year fallow while the bare soil land use was made up of a less than six (< 6) months old bare soil with scanty grass outcrop.

In each land use, undisturbed soil core using the core sampler and disturbed soil samples using the auger were randomly collected at two depths (0-15 and 15-30 cm)from two locations. The 0-15 cm soil depth represented the top soil while the 15-30cm soil depth the subsoil. A total of 16 soil samples were collected. The soil samples were air dried and sieved through a 2 mm diameter mesh. Sub samples of the soil fine earth fraction (< 2 mm) were stored for soil characterization while the other was fractionated and used for carbohydrate determination.

2.2 Particle Size Fractionation

Particle size fractionation was conducted on a subsample of the fine earth soil fraction (< 2 mm diameter) according to the method described by Amelung et al. (1998). In this, 30 g soil sample was treated ultrasonically with energy input equivalent to 60J mL^{-1} using a probe type sonicator (Branson Sonifer W 450) in a soil: water ratio of 1:5. The sand fraction (20-2000 µm) was isolated by wet sieving. Another energy input of 440 J mL^{-1} was applied using the sonicator to a soil: water ratio of 1:10 for complete dispersion of materials remaining after the removal of the sand fraction. The clay fraction (< 2 µm) was separated by repeated centrifugation while the silt fraction (2-20 µm) was separated by wet sieving. All fractions recovered were then dried at 40^oC and stored in clean plastic containers.

2.3 Soil Analyses

2.3.1 Routine Analyses

Routine analyses was conducted on the subsamples of the fine earth soil fraction and the following soil characteristics determined; particle size (Gee and Or, 2002), soil pH in 1:2.5 soil/water ratio using glass electrode of the pH meter, OM (Nelson and Sommers, 1996), total N (Bremner, 1996) and CEC (Herrmann, 2005).

2.3.2 Carbohydrate Determination

Total carbohydrate, cold water, hot water and dilute acid carbohydrate contents in the bulk soil (< 2000 µm) and soil particle size fractions (< 2 µm, 2-20 µm and 20-2000 µm) were determined as follows:
One gram subsample of the soil was mixed with concentrated H_2S0_4 (98% analytical grade) solution in a 50 ml centrifuge tube and hydrolyzed for 16 hrs by shaking on a rotary shaker (Total carbohydrate).

- Ten (10) milliliter of 0.25M H_2S0_4 solution was added to 1g subsample of the soil in a 50 ml centrifuge tube and hydrolyzed for 16 hrs by shaking on a rotary shaker (dilute sulphuric acid extractable carbohydrate).
- One gram subsample of the soil was mixed with 10 mL of hot distilled water (85^{o}C) and heated for 2.5 hr (hot water extractable carbohydrate).
- One gram subsample of soil was mixed with 10 mL of cold distilled water (25 ^{o}C) in a 50 ml centrifuge tube and shaken on a rotary shaker for 16 hr (cold water extractable carbohydrate).

All extractions were in duplicates and the suspensions centrifuged at 5800 x g for 10 min. The clear supernatants were decanted into a 20 ml plastic container and 2 mls aliquot of the supernatant used to determine the carbohydrate content using the phenol-sulphuric acid method (Piccolo et al., 1996).

2.4 Statistical Analysis

Data generated were subjected to analysis of variance (ANOVA) and means separated at 5% confidence interval using genstat statistical package (Buysse et al., 2004). Relationship between extractable carbohydrates and the bulk soil extractable carbohydrates with selected soil properties were determined using correlation analysis. Predictive equations of bulk soil and particle size extractable carbohydrates were determined using regression analysis.

3.0 Results

3.1 Physicochemical Properties of Soils Studied

Texture of the soils varied as sandy loam, loamy sand and sandy clay loam, with most being dominantly sandy (Table 1). Magnitude of coarseness of the soils was higher in the fallow than the other land use types. Soil moisture contents varied as 72.7-113.8 and 104.3-120.1 g kg^{-1} in the top and sub soils respectively, with the later better than the former. Bulk densities varied as 1.41, 1.32, 1.40 and 1.31 in the topsoil and 1.29, 1.45, 1.37 and 1.30 g cm^{-3} in the sub soils of bare soil, cassava, fallow and oil palm land uses respectively, with the oil palm lower and the cassava and fallow land uses higher than the others. Soil organic matter was low, with the largest concentration being in Oil Palm land use with the least bulk densities (1.31 and 1.30 g cm^{-3} in the topsoil and subsoil respectively). Mean organic matter content varied as 18.18, 22.40, 23.18 and 29.65 g kg^{-1} in the bare soil, cassava, fallow and oil palm land uses respectively and with the oil palm land use higher than the others. Concentrations of soil nutrients (N, P, Ca, Mg and K) in all land uses were low, with the magnitudes better with increased organic matter contents. Soil ECEC was low and below 16 cmol (+) kg^{-1} in all land uses. Soil pH was low and ranged from 5.40-6.66 and 5.30-5.58 in the top and sub soils respectively.

3.2 Soil Carbohydrate Contents and Enrichment Factors

Total, dilute acid, hot water and cold water extractable carbohydrates are presented in Tables 2, 3, 4 and 5 respectively. In Table 2, total carbohydrate content of the bulk soil ranged from 9.50-30.00 (18.10 g kg^{-1}) and 11.10-33.60 (22.50 g kg^{-1}) in the top and sub soils respectively with the later higher than the former. Concentrations in the Oil palm and bare soil land uses were none significantly ($P < 0.05$) higher than others in the top and sub soils respectively. Total carbohydrate content of the soil fractions ranged from 5.70-39.60 (19.98 g kg^{-1}) and 9.30-28.20 (19.03 g kg^{-1}) in the sand fraction, 3.90-20.70 (12.93 g kg^{-1}) and 7.80-22.50 (14.70 g kg^{-1}) in the silt fraction and 19.60-58.60 (40.63 g kg^{-1}) and 29.30-52.10 (44.55 g kg^{-1}) in the clay fraction for the top and sub soils respectively, with the later better than the former in most of the soil fractions. In both soil depths, total carbohydrate content increased in the order silt < sand < clay fractions. Enrichment factors ranged from 1.12-2.14 (1.70) and 0.69-1.45 (1.07), 0.26-2.67 (1.42) and 0.69-1.45 (0.80) and 0.91-6.53 (4.56) and 0.95-9.00 (mean = 4.06) in the sand, silt and clay fractions for the top and sub soils respectively, with the top soil more enriched than the sub soil for all fractions and with clay > sand > silt for the soil fractions of both soil depths. Oil palm was none distinctly ($P < 0.05$) higher in total carbohydrate content of the sand fraction while cassava was in the silt and clay fractions than the others for the top soil. Bare soil had the best concentration in the sand and silt fractions while Oil palm was in the clay fraction in the subsoil. Also cassava, fallow and bare soil were more enriched in the sand, silt and clay fractions respectively in the top soil while fallow was in the sand fraction and oil palm in the silt and clay fractions in the sub soil.

Dilute acid extractable carbohydrate content of the bulk soil was similar amongst the various land uses in the top soil but ranged from 0.13-0.56 (0.33 g kg^{-1}) in the sub soil, with cassava, none distinctly better than the other land uses (Table 3). Mean concentration of the top soil (0.32 g kg^{-1}) was similar to that of the subsoil (0.33 g kg^{-1}). Concentrations of the soil fractions ranged from 0.25-0.92 (0.45 g kg^{-1}), 0.37-0.48 (0.42 g kg^{-1}) and 0.41-

1.12 (0.77 g kg^{-1}) in the top soil and 0.28-0.42 (0.37 g kg^{-1}), 0.27-0.65 (0.46 g kg^{-1}) and 0.69-0.77 (0.74 g kg^{-1}) in the sub soil for the sand, silt and clay fractions respectively. Besides, the silt fraction, concentrations of the sand and clay fractions were higher in the top than the sub soil, with variations amongst fractions being an increasing order of silt < sand < clay and sand < silt < clay in the top and sub soils respectively. Concentrations of the clay fraction were higher than the others in both soil depths. Contents of the sand and clay fractions were none significantly higher in cassava while that of the silt fraction was in the bare soil than the other land uses in the top soil. Bare soil land use was significantly higher than fallow but none significantly with the others in the sand fraction while Fallow was none distinctly higher than the other land uses in the silt and clay fractions of the sub soil. Enrichment factors ranged from 0.79-2.49 (1.33) and 0.95-2.20 (1.64), 1.16-1.57 (1.33) and 1.07-3.64 (2.10) and 1.35-3.47 (2.40) and 1.81-6.04 (3.43) in the sand, silt and clay fractions of the top and sub soils respectively, with the later more enriched than the former in all soil fractions. Carbohydrate enrichment increased with decreased soil particle size (1.49, 1.72 and 2.92 in the sand, silt and clay fractions respectively).

Hot water soluble carbohydrate content of the bulk soil ranged from 0.03-0.07 (0.05 g kg^{-1}) and 0.02-0.08 (0.05 g kg^{-1}) in the top and sub soils respectively, with oil palm better than the other land uses in both soil depths (Table 4). Sand, silt and clay fraction carbohydrate contents ranged from 0.06-0.15 (0.11 g kg^{-1}) and 0.07-0.23 (0.12 g kg^{-1}), 0.09-0.19 (0.13 g kg^{-1}) and 0.09-0.19 (0.12 g kg^{-1}) and 0.14-0.26 (0.21 g kg^{-1}) and 0.12-0.21 (0.17 g kg^{-1}) in the top and sub soils respectively, with mean concentration in the soils increased with decreased particle size fraction. Oil palm land use was none seriously better in the sand and clay fractions than the others in both top and sub soil depths while fallow and bare soil land uses were none distinctly better than others in the silt fraction of the top and sub soil respectively. Enrichment factors ranged from 2.31-5.25 (3.72) and 1.70-4.25 (2.77), 1.88-7.75 (3.80) and 1.48-10.20 (4.10) and 3.52-10.25 (6.86) and 2.30-11.00 (5.16) in the sand, silt and clay fractions of the top and sub soils respectively, with sand and clay fractions more enriched in the top soil and the reverse for the silt fraction. Mean enrichment amongst the soil fractions were 3.25, 3.95 and 6.01 for sand, silt and clay fractions, indicating that hot water soluble carbohydrate enrichment increased with decreased soil particle size fraction. Bulk soil cold water soluble carbohydrate content (Table 5) ranged from 0.04-0.14 (0.09 g kg^{-1}) in the top soil and 0.11-0.20 (0.14 g kg^{-1}) in the sub soil, with concentrations in the later larger than the former. Concentrations of the soil fractions ranged from 0.05-0.39 (0.18 g kg^{-1}) and 0.10-0.32 (0.17 g kg^{-1}), 0.03-0.13 (0.08 g kg^{-1}) and 0.07-0.21 (0.13 g kg^{-1}) and 0.07-0.19 (0.11 g kg^{-1}) and 0.03-0.07 (0.05 g kg^{-1}) in the top and sub soils of the sand, silt and clay fractions respectively, with the sand and clay fractions higher in the top soil and the reverse being the case for the silt fraction. Mean concentrations of the various fractions were 0.18, 0.11 and 0.08 g kg^{-1} in the sand, silt and clay fractions respectively indicating a decreased carbohydrate concentration with decreased soil particle size fraction. Enrichment factors ranged from 0.86-6.87 (2.98) and 0.61-4.19 (1.80), 0.50-1.67 (0.97) and 0.56-1.17 (0.93) and 0.49-3.59 (1.91) and 0.39-0.93 (0.56) in the top and sub soils for the sand, silt and clay fractions. Mean enrichment factors for the soil fractions were 2.39, 0.95 and 1.24 for the sand, silt and clay soils respectively, showing a decrease of sand > clay > silt fractions. Cassava was more enriched in all soil fractions in the top soil and the sand fraction in the subsoil while fallow and oil palm were better in the silt and clay fractions respectively for the subsoil.

3.3 Relationship between soil Carbohydrate Concentrations and Soil Properties

Relationships amongst various extractable carbohydrates in the bulk soil and the pedotransfer function of the bulk soil carbohydrate concentrations with the contents of the soil fractions are presented in Table 6 while that between bulk soil carbohydrate content and soil properties is in Table 7. Total carbohydrate extracted with concentrated H_2S0_4 significantly ($P< 0.05$) correlated with hot water soluble ($r = 0.55$) but not dilute acid soluble ($r = 0.23$) and cold water soluble ($r = 0.25$) carbohydrates (Table 6). Also dilute acid soluble carbohydrate was not distinctly correlated with hot water ($r = 0.13$) and cold water soluble ($r = 0.33$) carbohydrates. Equally, hot and cold water soluble carbohydrates were not seriously correlated ($r = -0.11$) with each other. Carbohydrate content of the bulk soil was positively and more seriously related with the carbohydrate contents of the sand and silt than the clay fractions as indicated by the slopes (0.77, 0.90 and 0.42 for sand, silt and clay fractions respectively) of the regression equations. Regression model (Table 6) indicates that carbohydrate concentration of the bulk soil could be accounted by about 69, 58 and 47% of that in the sand, clay and silt fractions respectively. Extractable carbohydrate concentrations of the bulk soil correlated with selected soil properties (Table 7). For instance, total extractable carbohydrate correlated significantly and positively with the silt content ($r = 0.42$) and negatively with soil pH ($r = -0.53$) but none significantly with sand ($r = -0.23$), clay ($r = 0.08$), silt + clay ($r = 0.23$), OM ($r = 0.24$) and ECEC ($r = 0.001$). Hot water soluble carbohydrate correlated seriously with silt content ($r = 0.65$), OM ($r = 0.77$) and ECEC ($r = -0.48$) but not with sand content ($r = 0.21$), clay content ($r = -0.35$), silt + clay ($r = -0.21$) and pH ($r = -0.21$). Besides soil pH ($r = -0.61$) which correlated significantly, sand ($r = -0.37$), silt ($r = 0.07$), clay ($r = 0.29$), silt + clay ($r = 0.37$), OM ($r = -0.18$) and ECEC ($r = -0.10$) correlated none significantly with cold water soluble carbohydrate. There was no distinct correlation between dilute acid soluble carbohydrate and all the soil properties (sand ($r = -0.09$), silt ($r = 0.02$), clay ($r = 0.07$), silt + clay (r =

0.09), OM (r = 0.17), pH (r = -0.10) and ECEC (r = -0.38).

4.0 Discussion

Sandiness of the soils indicates that they are of the same origin, Coastal Plain Sands (Orajiaka, 1975). Coarse nature of the soils suggests that nutrient leaching and loss would be high and this probably explained the poor nutrient (N, P, Ca, Mg, K and ECEC) and low fertility status of the soils. Similar observation has been reported for Ultisols of southeastern, Nigeria (FMANR, 1990). Soil organic matter was low and could be responsible for the low nutrient status, low ECEC and high bulk density (FMNAR, 1990; Hargreaves et al., 2008) since fertility of tropical soils has been related to their organic matter content (Spaccini et al., 2001). High acidity of the soils has been ascribed to the intense leaching of bases by the high tropical rainfall (FMANR, 1990).

Magnitude of extractable carbohydrates decreased in the order total > dilute acid soluble > hot water soluble > cold water soluble in response to the chemistry of the extractants (Herbert and Bertsch 1995). It has been indicated that the amount of carbohydrates extracted increases with increasing acid concentration and temperature of hydrolysis (Gregorich et al., 1994). Concentrations of various extractable carbohydrates (total, dilute acid soluble, hot water soluble and cold water soluble) in the top and sub soils of the bulk soil and soil fractions varied with the land use types probably in response to the soil properties and environmental conditions. Similar observation has been noted for carbohydrates and SOM in soils of varying land uses (Zhang et al., 1999; Spacini et al., 2001; Schmidit and Kogel-Knabner, 2002). Except cold water soluble carbohydrate which was higher in the sand fraction, extractable carbohydrates using the other reagents were better in the clay fraction and increased with decreasing particle size fraction, irrespective of the land use type. Dominance of carbohydrate in the clay than the other particle size soil fractions have been reported by other workers (Oades et al., 1987; Dalal and Henery, 1988; Gubbenberger et al., 1994; Zhang et al., 1999) and attributed to increased surface area and capacity for high adsorption as well as tendency of complexion into clay-organic matter complex (Spacini et al., 2001). Carbohydrate, in the clay fraction represents the stable SOM fraction that is not susceptible to microbial decomposition (Evans et al., 2001). Thus, though much of the carbohydrates in soils of these land uses are present in the stable form, they still exhibited great degree of lability, with the extent probably depending on the dominant carbohydrate pools or monomer present and soil properties (Lowe, 1993). High concentration and enrichment of carbohydrate in the clay fractions of these soils may suggest that improving their SOM content through organic manure addition could help promote carbon storage or sequestration, since they would be stabilized in the clay fraction. Also the dominance and enrichment of water soluble carbohydrate in the sand fraction of the soils explains the importance of the different extractants in estimating specific labile carbohydrate forms. Sand fraction has been reported to contain the most labile and mobile carbohydrate forms than the silt and clay fractions (Tiessen and Stewart, 1983). Cold water, being a weak extractant, estimated only this fraction, thus suggesting its usefulness in the determination of the most available and soluble soil carbohydrate fraction. This fraction consists mainly of the non-structural plant carbohydrate and the extracellular microbial carbohydrate (Haynes et al., 1993). Capacities of the various reagents for the extraction of soluble carbohydrates varied depending on their chemistry (Cheshire, 1979) and soil properties.

5.0 Conclusion

Soils of the various land uses varied with their physical and chemical properties. Magnitude of extractable carbohydrate varied depending on the chemistry of the extractant and the properties of soils of the various land uses. Except the most labile and mobile carbohydrate (cold water soluble carbohydrate) that was enriched in the sand fraction, carbohydrate concentrations of the various land use types were enriched in the clay fraction. Carbohydrate concentrations and enrichment of both top and sub soils of the various land uses differed depending on the soil and environmental conditions. Besides concentrated H_2S0_4 extractable carbohydrate which significantly correlated with hot water soluble carbohydrate, there was no distinct intercorrelation amongst others. Carbohydrate content of bulk soils were closely related to the contents of the soil fractions especially, silt and sand fractions. Soil properties especially, sand, silt, clay, silt+clay, OM, pH and ECEC affected soil carbohydrate concentrations.

References

Amelung, W., Zech, W., Zhang, X., Follett, R.F., Tiessen, H.,Knox, E., Flach, K.-W., 1998. Carbon, nitrogen, and sulfur pools in particle size fractions as influenced by climate. Soil Science Society of America Journal 62, 172-181.

Angers. D. A and G. R. Mehuys 1990. Barley and alfalfa cropping effects on carbohydrate contents of a clay soil and its size fractions. Soil Biology and Biochemistry 22, 285–288.

Arshad, M.A, M.Schnitzer, M.A.Angers and J.A.Ripmeester 1990. Effects of till versus no till on the quality of soil organic matter.Soil Biology and Biochemistry 22, 595-599.

Bremner J.M, 1996. Nitrogen-total, in Methods of Soil Analysis. Part3. Chemical Methods, Vol. 5 of Soil Science Society of America Book Series, ed. by Sparks DL. Soil Science Society of America/American Society of Agronomy, Madison, WI, pp. 1085–1122.

Buysse, W, R.Stern and R.Coe 2004 Genstat Discovery Edition for everyday use. ICRAF Nairobi, Kenya 114 pp. Chesire, M.V, B.T.Christensen and L.H.Sorensen 1990. Labeled and native sugar in particle size fractions from soils incubated with 14C straw for 6 and 18 years. Journal of Soil Science, 21, 29-39.

Cheshire M. V 1979. Nature and Origin of Carbohydrates in Soils. Academic Press, London.

Dalal, R. C and R. J. Henry 1988. Cultivation effects on carbohydrate contents of soil and soil fractions. Soil Science Society America Journal 52, 1361–1365.

Debosz, K, L. Vognsen and R. Labouriau 2002. Carbohydrates in hot water extracts of soil aggregates as influenced by long-term management. Communication in Soil Science and Plant Analysis 33(3&4), 623–634

Evans, J. L, J.F. Ivan, E.R.Lindsey and S.A.Norton 2001. Methods for Evaluating Carbon Fractions in Forest Soils: A Review. Technical Bulletin, 178. Maine agricultural and forest experimentation station, The University of Maine FMANR (Federal ministry of Agriculture and natural resources) 1990. Literature review on soil fertility investigations in Nigeria (five volumes). Bobma Publishers, Ibadan Nigeria.

Gee, G.W and D. Or.2002. Particle size distribution. In Dane, J/H and G.C.Topp (eds). Methods of soil analysis. Part 4. Physical and mineralogical methods. Soil Science Society of America book series. No.5 ASAS and SSA. Madision, Wisconsin. p 255-293.

Ghani, A, M. Dexter and W.K Perrott 2003. Hot-water extractable carbon in soils: a sensitive measurement for determining impacts of fertilization, grazing and cultivation. Soil Biology and Biochemistry. 35, 1231–1243.

Gregorich, E.G., M.R. Carter, D.S. Angers, C.M. Monreal, and B.H. Ellert 1994. Towards a minimum data set to assess soil organic matter quality in agricultural soils. Canadian Journal Soil Science. 74,367–385.

Guggenberger, G., B.T. Christensen and W Zech 1994. Land use effects on the composition of organic matter in soil particle size separates: I. Lignin and carbohydrate signature. European Journal of Soil Science.45, 449-458

Hargreaves, J.C, M.S.Adl and P.R.Warman 2008. A review of the use of composted municipal solid waste in agriculture. Agriculture Ecosystems and Environment 123 (1-3), 1-14.

Haynes, R.J and G.S. Francis.1993. Changes in Microbial Biomass C, Soil Carbohydrate Composition and Aggregate Stability Induced by Growth of Selected Crop and Forage Species under Field Condition. Journal of Soil Science 44, 665–675.

Herbert, B.E and P.M. Bertsch. 1995. Characterization of dissolved and colloidal organic matter in soil solution: a review. In Carbon Forms and Functions in Forest Soils, ed. W.W. McFee and M. Kelly. Soil Society of America, Inc. Madison, WI.

Herrmann, L., 2005. Soil Analysis. University of Hohenheim Press, Germany, pp. 32–40 (in German).

IPEDC (Imo State Planning and Economic Development Commission) 2006. Imo state of Nigeria statistical year book. Published by Imo State Planning and Economic Development Commission, State Secretariat, Portharcourt road, 282pp.

Insam, H 1996. Microorganisms and humus in soils. In Piccolo A (Ed). Humus substances in terrestrial ecosystems (256-292). Elsevier Amsterdam.

Lekwa, O. and E.P. Whiteside 1986. Coastal Plain Sands of Southeastern Nigeria. Morphology, classification and generic relationship. Soil Science Society of America Journal 50,154-156.

Lowe, L. E and A. A. Hinds 1983. The mineralization of nitrogen and sulphur from particle size separates of gley solic soils. Canadian Journal Soil Science 63, 761–766.

Mann, C.K., 1985. A regional comparison of carbon in cultivated and uncultivated Alfisols and Mollisols in the central United States. Geoderma 36, 241-253.

Mbagwu, J.S.C and A. Piccolo 1998. Water dispersible clay in aggregates of forest and cultivated soils in southeastern Nigeria in relation to organic matter constituents. In Bergrom L. and Kirchman H. (EDS) Carbon and nitrogen dynamics in natural and agricultural ecosystems (pp77-83) CAB International, UK.

Nelson DW and LE Sommers 1996.Total carbon, organic carbon and organic matter, in Methods of Soil Analysis. Part 3. Chemical Methods, Vol. 5 of Soil Science Society of America Book Series,ed. by Sparks DL. Soil Science Society of America/American Society of Agronomy, Madison, WI, pp. 96–101.

Oades J. M, A. M. Vassallo, A. G. Waters and M. A. Wilson 1987. Characterization of organic matter in particle size and density fractions from Red-Brown Earth by solid-state 13C NMR. Australian Journal of Soil Resources 25, 71–82.

Orajiaka, S.O. 1975. Geology. In Ofomata G.E.K (ed). Nigeria in maps, Eastern States. Ethiope Publishing house, Benin city. Pp 5-7.

Piccolo, A 1996. Humus and Soil Conservation. In Piccolo A (ed) Humic substances in terrestrial ecosystems (pp225-264). Elsevier, Amsterdam.

Puget, P and R. Lal. 2005. Soil organic carbon and nitrogen in a Mollisol in central Ohio as affected by tillage

and land use. Soil Tillage Resources. 80, 201–213.
Roberson, E.B, S. Sarig and M.K. Firestone 1991. Cover crop management of polysaccharide-mediated aggregation in an orchard soil. Soil Science Society of America Journal 55, 734-738.
Schmidit, M.W, I and I. Kogel-Knabner 2002. Organic matter in particle-size fractions from A and B horizon of Haplic Alisol. European Journal of Science 53, 383-391.
Schulten, H.R., R.Hempfling, K.Haider, F.F. GroÈblinghoff, H.D LuÈdemann and R. FruÈnd1990. Characterization of cultivation effects on soil organic matter. Z. PflanzenernaÈhr. Bodenkd.153, 97-105.
Solomon D, J. Lehmann and W. Zech 2000. Land use effects on soil organic matter properties of chromic Luvisols in semi-arid northern Tanzania: carbon, nitrogen, lignin and carbohydrates. Agriculture, Ecosystems and Environments. 78, 203–213.
Spaccini, A. Zena, C.A.Igwe, J.S.C.Mbagwu and A. Piccolo. 2001. Carbohydrates in water stable-aggregates and particle size fractions of forested and cultivated soils in two contrasting tropical ecosystems. Biogeochemistry 53, 1-22.
Stevenson, F.J. 1994. Humus Chemistry: Genesis, Composition, Reactions. John Wiley and Sons, Inc., New York. Tiessen, H and J. W. B. Stewart, 1983. Particle-size fractions and their use in studies of soil organic matter: II Cultivation effects on organic matter composition in size fractions. Soil Science Society of America Journal. 47, 509–514.
Tisdall, J.M and J.M. Oades. 1982. Organic matter and water-stable aggregates in soils. Journal of Soil Science. 33, 141–163.
Zhang. X, W. Amelung, Y. Yuan, S. Samson-Liebig, L. Brown and W. Zech 1999. Land-use effects on amino sugars in particle size fractions of an Argiudoll. Applied Soil Ecology. 11, 271-275.

Table 1. Characterization of Soils of the land use types studied

Parameters	Units	Bare soil	Cassava	Fallow	Oil Palm	Bare soil	Cassava	Fallow	Oil Palm
		Top soil (0-15 cm)				Subsoil (15-30 cm)			
Sand	g kg^{-1}	800.2a	836.6a	853a	828a	760.2b	805.2b	838a	813b
Silt	g kg^{-1}	20.6a	30.6a	40.6a	45.6a	25.6a	25.6a	30.6a	45.6a
Clay	g kg^{-1}	179.2a	132.8a	106.4a	126.4a	214.2a	169.2ab	131.4b	141.4b
TC		SL	LS	LS	SL	SCL	SL	SL	SL
Bd	g cm^{-3}	1.41a	1.32a	1.40a	1.31a	1.29a	1.45a	1.37a	1.30a
MC	g kg^{-1}	107.8a	89.3a	72.7a	113.8a	118.0a	104.3a	104.9a	120.1a
pH		6.66a	5.45b	5.54b	5.40b	5.34a	5.46a	5.58a	5.30a
Avail P	mg kg^{-1}	28.98a	29.61a	14.39a	19.43a	12.65a	23.84a	15.09a	14.35a
Total N	g kg^{-1}	0.45c	0.85b	0.90b	1.35a	0.55a	0.65a	0.75a	1.05a
OM	g kg^{-1}	18.60c	23.45b	25.00b	31.55a	17.75c	21.35b	21.35b	27.75a
C/N ratio		25.12a	16.88ab	17.17ab	13.83b	20.13a	20.09a	19.12a	17.94a
Ca	cmol (+) kg^{-1}	4.88a	0.25b	1.05b	0.65b	3.25a	0.20b	0.90b	0.45b
Mg	cmol (+) kg^{-1}	1.55a	0.50a	1.00a	0.66a	1.00a	0.25a	1.00a	0.42a
K	cmol (+) kg^{-1}	0.20a	0.20a	0.20a	0.20a	0.20a	0.20a	0.20a	0.20a
Na	cmol (+) kg^{-1}	0.11a	0.12a	0.10a	0.10a	0.10b	0.10b	0.14a	0.10a
ECEC	cmol (+) kg^{-1}	6.74a	1.26b	2.54ab	1.84b	4.69a	1.01b	2.44ab	1.46b

Means followed by the same letter are not significantly different at $p < 0.05$ for each soil depth.
Bd = Bulk density, TC =Textural class, MC = Moisture content, OM = Organic matter and Avail P = Available P

Table 2. Total carbohydrate contents and Enrichment factors of Soils of different land uses

	Total carbohydrate (g kg^{-1})				**Enrichment factors**			
Land use	Bulk soil	Sand	Silt	Clay	Bulk soil	Sand	Silt	Clay
				Top soil (0-15 cm)				
Bare soil	9.50	5.70	3.90	19.60	1.00	2.13	1.34	6.53
Cassava	11.80	18.20	20.70	58.60	1.00	2.14	1.41	5.71
Fallow	21.10	16.40	20.30	54.30	1.00	1.40	2.67	5.08
Oil Palm	30.00	39.60	6.80	30.00	1.00	1.12	0.26	0.91
LSD 0.05	36.68	59.57	38.26	30.35	0.00	7.12	4.13	15.37
				Sub soil (15-30 cm)				
Bare soil	33.60	28.20	22.50	29.30	1.00	0.69	0.50	0.95
Cassava	11.10	9.30	8.20	47.50	1.00	0.98	0.72	4.27
Fallow	24.20	27.50	20.30	49.30	1.00	1.17	0.84	2.02
Oil Palm	21.10	11.10	7.80	52.10	1.00	1.45	1.13	9.00
LSD 0.05	52.48	45.40	50.30	49.44	0.00	3.21	2.39	16.71

Bulk soil = < 2000 µm, Sand = 20-2000 µm, Silt =2-20 µm and Clay = <2 µm

Table 3. Dilute Acid Soluble carbohydrate content (g kg^{-1}) and Enrichment factors of Soils of different land uses

	Dilute Acid soluble carbohydrate				**Enrichment factor**			
Land use	Bulk soil	Sand	Silt	Clay	Bulk soil	Sand	Silt	Clay
				Top soil (0-15 cm)				
Bare soil	0.31	0.37	0.48	0.41	1.00	1.21	1.57	1.35
Cassava	0.33	0.92	0.37	1.12	1.00	2.49	1.16	3.47
Fallow	0.32	0.25	0.40	0.73	1.00	0.79	1.25	2.29
Oil Palm	0.32	0.26	0.43	0.79	1.00	0.81	1.34	2.47
LSD 0.05	0.20	1.27	0.21	0.84	0.00	2.36	0.58	1.22
				Sub soil (15-30 cm)				
Bare soil	0.24	0.42	0.27	0.76	1.00	1.82	1.21	3.46
Cassava	0.56	0.41	0.51	0.74	1.00	1.57	2.47	2.42
Fallow	0.13	0.28	0.65	0.77	1.00	2.20	3.64	6.04
Oil Palm	0.38	0.36	0.41	0.69	1.00	0.95	1.07	1.81
LSD 0.05	0.88	0.12	0.49	0.64	0.00	3.20	4.31	6.44

Bulk soil = < 2000 µm, Sand = 20-2000 µm, Silt =2-20 µm and Clay = < 2µm

Table 4. Hot Water Soluble Carbohydrate content (g kg^{-1}) and Enrichment factors of Soils of different land uses

	Hot Water Soluble Carbohydrate				**Enrichment Factor**			
Land use	Bulk soil	Sand	Silt	Clay	Bare soil	Sand	Silt	Clay
			Top soil (0-15 cm)					
Bare soil	0.04	0.06	0.11	0.14	1.00	4.25	2.58	7.33
Cassava	0.04	0.09	0.09	0.18	1.00	3.05	3.00	6.35
Fallow	0.03	0.13	0.19	0.25	1.00	5.25	7.75	10.25
Oil Palm	0.07	0.15	0.13	0.26	1.00	2.31	1.88	3.52
LSD 0.05	0.08	0.17	0.19	0.41	0.00	13.50	9.07	21.70
			Sub soil (15-30 cm)					
Bare soil	0.02	0.07	0.13	0.16	1.00	4.25	10.20	11.00
Cassava	0.05	0.09	0.11	0.12	1.00	1.70	2.20	2.30
Fallow	0.04	0.08	0.10	0.18	1.00	2.10	2.53	4.67
Oil Palm	0.08	0.23	0.12	0.21	1.00	3.01	1.48	2.67
LSD 0.05	0.04	0.25	0.16	0.09	0.00	4.88	15.50	2.67

Bulk soil = < 2000 µm, Sand = 20-2000 µm, Silt =2-20 µm and Clay = < 2µm

Table 5. Cold Water Soluble Carbohydrate content (g kg^{-1}) and Enrichment factors of Soils of different land uses

	Cold Water Soluble Carbohydrate				**Enrichment Factor**			
Land use	Bulk soil	Sand	Silt	Clay	Bare soil	Sand	Silt	Clay
			Top soil (0-15 cm)					
Bare soil	0.04	0.05	0.03	0.07	1.00	1.50	0.80	2.00
Cassava	0.06	0.39	0.09	0.19	1.00	6.87	1.67	3.59
Fallow	0.14	0.11	0.13	0.07	1.00	0.86	0.89	0.49
Oil Palm	0.10	0.16	0.05	0.11	1.00	2.70	0.50	1.57
LSD 0.05	0.08	0.21	0.25	0.34	0.00	5.27	3.58	6.22
			Sub soil (15-30 cm)					
Bare soil	0.20	0.11	0.21	0.05	1.00	0.61	0.83	0.41
Cassava	0.13	0.32	0.09	0.07	1.00	4.19	0.56	0.51
Fallow	0.13	0.10	0.13	0.03	1.00	0.96	1.17	0.39
Oil Palm	0.11	0.13	0.07	0.06	1.00	1.43	1.16	0.93
LSD 0.05	0.44	0.25	0.51	0.10	0.00	7.24	2.91	1.82

Bulk soil = < 2000 µm, Sand = 20-2000 µm, Silt =2-20 µm and Clay = < 2µm

Table 6. Simple Correlation (r) between Total, Dilute acid, Hot water and Cold water Carbohydrate Concentrations and the Pedotransfer Function of Carbohydrate Content of Bulk soil and the Contents of the Soil Fractions

A. Correlation Coefficients of total, dilute acid, hot water and cold extractable carbohydrates		
Parameters	r	
Total vs. Dilute acid soluble carbohydrate	0.23	
Total vs. hot water soluble	0.55	
Total vs..cold water soluble carbohydrate	0.25	
Dilute acid vs. cold water soluble carbohydrate	-0.33	
Dilute acid vs. hot water soluble carbohydrate	0.13	
Hot water vs. cold water soluble carbohydrate	-0.11	
B. Pedotransfer functions of Bulk and Soil Fraction of Carbohydrate Contents		
Parameters	Equations	r^2
Bulk soil vs. Sand fraction	Y = 1.33 + 0.77x	0.69
Bulk soil vs. Silt fraction	Y = 1.95 + 0.90x	0.47
Bulk soil vs. Clay fraction	Y = 0.57 + 0.42x	0.58

Table 7. Simple Correlation between bulk soil Carbohydrate content and selected soil properties

	Sand	Silt	Clay	Silt + Clay	OM	pH	ECEC
Total Carbohydrate,	-0.23	0.42	0.08	0.23	0.24	-0.53	0.001
Dil. Acid Soluble Carbohydrate.	-0.09	0.02	0.07	0.09	0.17	-0.10	-0.38
Hot Water soluble Carb.	0.21	0.65	-0.35	-0.21	0.77	-0.21	-0.48
Cold Water soluble Carb.	-0.37	0.07	0.29	0.37	-0.18	-0.61	-0.10

Carb. = Carbohydrate, Dil. = Dilute, OM = Organic natter and ECEC = Effective cation exchange capacity