Physical and Chemical Characterisation of Agricultural Plant Residues from Some Farming Systems for their Sustainable Utilisation.

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Abstract

Due to farming activities, large amounts of organic residues are generated daily in farms. These residues can be used for many purposes however, their chemical and physical characterization is important when planning their management and usage. In this study, chemical and physical properties of cocoa pod husk, senescent cocoa leaves, fresh and decaying banana pseudo stem, fresh palm fronds, palm empty fruit bunches, palm male inflorescence and senescent rubber leaves were determined. The moisture content, pH, and total concentrations of P, S, K, Ca, Mg, Mn, Zn, Cu, and B as well as available levels of P, K and Mg were analyzed. The available levels of P, K and Mg ranged between 0.03 and 0.39%, 0.47 and 8.81% and 0.04 and 0.20% respectively. The total levels of Ca, K, Mg and P respectively ranged between 0.16 – 2.47%, 0.50 – 10.32%, 0.16 – 0.95% and 0.07 – 0.51%. The B, Cu, Fe, Mn, S and Zn concentrations ranged respectively between 10.73 – 43.67 mg/kg, 9.07 – 61.13mg/kg, 100.67 – 1828.67mg/kg, 46.23 – 1717.33mg/kg, 1016.67 – 1800.67mg/kg and 28.57 – 422.00mg/kg. The properties of these residues varied significantly and their uses will equally be different.

Keywords: Banana, cocoa, litter, microelements, oil palm, para rubber, organic waste,

Introduction

Farm residues in the form of litter and plant post-harvest wastes are common in most farming systems. These materials are most often left to rot in farms providing some nutrition for the growing crops (in case of perennial crops) or for crops in the next season for annual crops. The chemical and physical characterization is important when planning the use and management of farm residues.

Plant litter especially leaf litter is very abundant in many farming systems like cocoa, coffee and para rubber. The decomposition of plant litter is an important driver for the cycling of carbon as well as nutrients and therefore plays a significant role in the structure and function of ecosystems (Jing et al., 2016, Mishra and Kumar 2016). Decomposition is mainly regulated by climate, litter quality, and the decomposer community (Knoepp et al., 2000). In the tropics litter decomposition is particularly important for ecosystem productivity because soils are highly weathered and therefore sometimes nutrient-poor (Martius et al., 2004). For the majority of cocoa farmers, fertility of soils under cocoa plantations is maintained through the recycling of nutrients through leaf fall and decomposition of leaf litter (Appiah et al., 2006). According to Evans et al., 2010, total litterfall production in cocoa farms in Ghana ranged from 5.0–10.4 Mg DM ha−1yr−1.

Cocoa pod husk also forms an important source of cocoa farm residue. Although there are studies on the use of these materials for crop fertilisation (Agyarko and Asiedu, 2012, Adejobi et al., 2013), a good quantity of it is still left in farms where they rot on their own (Syamsiro et al., 2012). The potential of using cocoa pod husk as components of feed have been studied Ashade, and Osineye, 2010, Norteyet al., 2015. High concentrations of potash were obtained from cocoa pod husk which suggested that the ash could possibly be used directly as a potash fertilizer substitute or the potash could be extracted from the ash and used as alkali for soft-soap making (Simpson, et al.,1985).

In the para rubber plantation ecosystem, leaf litter is a major contributor to nutrient cycling pathways (Seephueaka et al., 2010). According to Jacob, 2000, annual litter addition in rubber plantation amounts to 7 tonnes per hectare. These litters are not removed but persist on the plantation floor throughout the year and show a very slow rate of decomposition as indicated by only 16–21 percent weight loss for leaf litter within 120 days (Verghese et al., 2001). Nizami et al., 2018 found the average content of phosphorus and potassium in Hevea leaf litter collected from SW China to be 4.19 and 12.98 g/kg respectively. Rubber leaf litters was found to be a suitable vermiculture substrate for epigeic earthworms (Priyasankar et al., 2003).

Studies by Khalid et al., 2000 showed that during replanting, oil palm residues left onsite after the last harvest contributed a significant amount of nutrients that could be recycled in the plantation. Studies on the different parts of an oil palm tree showed that the fronds contained the highest quantities of K, Ca and P (Saka et al., 2008). Palm empty fruit bunches have been used as mulch and fertilizer supplements in plantations. (Nurul, 2015). The average nutrient contents of empty fruit bunches from different sources were P= 0.06%, K= 2.03% and Mg = 0.19% showing the EFB to be very rich in potassium (Nurul, 2015). Wingkis (1998) found that the nutrient contents in oil palm empty fruit bunch ranged thus; 0.76 – 0.96% N, 0.13 – 0.19% P, 1.21 – 3.20 % K, 0.36 -0.60 % Ca and 0.22 – 0.51% Mg. These nutrients were found to increase with decomposition.

The management of harvested (senescent) banana pseudostem was found to be very important in the nutrient use efficiency of banana plantations with most of their nutrients translocated to the attached growing pseudostems (Wortman et al., 1994). Banana pseudostem has been studied for its food value for humans (Ho et al., 2012) and fish (Patil and Kolambe, 2011). Banana pseudostem was found rich in macro nutrients in the order; K > Ca > Mg > P > Na (Ramu et al., 2017).

In tropical regions, organic materials are often more important than fertilisers in maintaining soil fertility, yet fertiliser recommendations and most crop models are unable to take account of the level and quality of organic inputs that farmers use. Smallholder farmers in the tropics rely to a large extent on organic inputs and biological processes for managing soil fertility. Biologically based farming systems range from annual cropping and fallow rotations involving biologically fixed nitrogen, to intensive continuous cropping with additions of manures and/or composts that may be augmented with inorganic fertilisers. There has been considerable progress in the past decade in understanding the role of organic materials in soil-nutrient availability and maintenance of soil organic matter (Delve and Probert, 2004).

The apparent neglect of nutrients from sources like animal manure, crop residues and the soil itself in designing nutrient models has contributed to soil nutrient levels that exceed agronomic requirements and to environmentally unacceptable large nutrient losses especially in intensively managed agroecosystems (Onene and Pietrzak, 2002). The physical and chemical properties of organic residues vary widely due to the heterogeneity of organic residues, even among materials from the same origin.

So far, limited information is available on the physico chemical properties of litters and residues from banana, cocoa, para rubber and oil palm farms in Cameroon. To maximised the use of on-farm resources, there is need for their characterisation to know their potential contributions to nutrient supplies as well as their other potential applications. Thus, the objective of this study was to determine the physico chemical properties of leaf litters, and other crop residues in banana, cocoa, para rubber and oil palm agroecosystems.

Materials and Methods

Field locations.

Samples were collected from some banana, cocoa, rubber and oil palm fields in the Fako Division of the South West region of Cameroon. The exact locations of the fields are presented in Table 1.

Table 1: **Description of sampling sites of the crop residues and litters used for the study.**

Land use type	Location	Longitude	Latitude	Elevation (m)	Soil type
Banana	Mussaka	04°˳11.468`	009o19.25`	477	Volcanic soil
Cocoa	Ekona	04o06 167`	009o23.51`	34	Volcanic soil
Rubber	Misellele	04o07.555`	009o26.62`	35	Volcanic soil
Oil palm	Maumu	04o12.29`	009o19.76`	437	Volcanic soil

Materials

Organic wastes collected from cocoa farms were cocoa pod husks andleaf litter (senescent leaves). In oil palm plantations the fronds (branches), the empty fruit bunches and the male inflorescence were collected. Leaf litter were collected in rubber plantations while in banana plantations, the pseudo stem was collected as the organic waste.

Sample collection

For each agroecosystem, 5kg of the organic wastes were collected and sun dried to constant weight. The dried samples were ground using a moulinex blender and sieved to a particle size of 2mm and packaged for analyses. Table 1 below shows the sample codes and their description.

Table 2. **Samples used and code names.**

Sample name	**Description**
CH	Cocoa pod husk
CL	Senescent cocoa leaves (litter)
BF	Fresh banana pseudostem
BD	Decaying banana pseudostem
PF	Fresh palm fronds
PB	Palm empty fruit bunches
PI	Palm male inflorescence
RL	Senescent rubber leaves (litter)

Chemical Analysis of Samples

All the crop residue samples were analysed for pH, organic matter, macro and micro nutrients.

Methods

The pH was measured in H_2O (ratio plant: water 1:2.5 w/v). Percentage ash content and organic matter (OM) was determined by loss on ignition using 0.5 g of sample heated up to 550 °C in a muffle furnace (Carbolite, UK) for 4 hours.

The samples were analysed for total macro (P, K, Ca and Mg) and total micro nutrients (Cu, Zn, Mn, Ni, Fe) following procedures summarised in Table 3. Soluble / plant available potassium, phosphorus and magnesium were also quantified and procedures are summarised in Table 3.

Table 3. Analytical methods used for the determination of residue elemental composition

Parameter	Analytical method		
	Extractant	Method of assay	Reference
Total elemental concentrations (P, K, Ca, Mg, Cu, Zn, Mn, Ni and Fe)	Microwave digestion with HNO3 and H2O2	Inductively coupled plasma optical emission spectroscopy (ICP-OES)	Ojeda and Rojas (2005)
Plant available/soluble concentrations (P and K)	Calcium Acetate Lactate (CAL) at ratio 1:20 (pH 4.1)	Inductively coupled plasma optical emission spectroscopy (ICP-OES)	Schueller (1969)
Plant available/soluble concentrations (Mg)	0.0125M $CaCl_2$	Inductively coupled plasma optical emission spectroscopy (ICP-OES)	Schachtschabel (1954)

Statistical Analysis

Data obtained were tested for statistical significance by using the analysis of variance package included in the JMP version 5 statistical package (SAS 2002). Mean comparisons were performed using the Turkey test at the probability level of $p \leq 0.05$.

Results and Discussions

A summary of the pH, ash and organic matter contents of the analysed samples is presented in Table 4. Most of the samples had a pH (water) very close to neutral (ranging between 5.8 and 10.3) except the decaying banana pseudostem (BD) and the fresh palm frond (PF) that ha values far from the neutral pH. According to Sharma et al. (1997), the pH range recommended for residues for agricultural use is 6 – 8.5. Samples from cocoa leaves and fresh palm fronds were within the tolerable pH range of 5.3 to 6.5 proposed by Abad et al., 2001for their usage as substrate materials. The studied samples were quite high in organic matter (81-94.5%) except for the decaying banana pseudostem (69%). The total organic matter for most of the studied residues was higher than 43.1% and 61.3% (respectively for herbal plant and sugar cane plant residues) that were obtained by El-Sayed in 2015. The highest organic carbon content was found in para rubber leaf litter (55%). This high level of organic matter is in agreement with the study of Naklang et al., 1999 who concluded that crop residues, leaf litter and green manures are needed to rehabilitate soil carbon.

Table 4. Some properties of the samples; pH, organic matter (%), ash (%) and organic carbon content.

Sample	pH(Water)	Organic Matter (%)	Ash Content (%)	[a]Organic Carbon
CH	8.2	91.7	8.3	53.3
CL	6.5	85.7	14.4	49.8
BF	9.3	80.9	19.1	47.0
BD	10.3	68.8	31.2	40.0
PF	5.8	91.2	8.8	53.0
PB	7.6	93.3	6.8	54.2
PI	7.6	88.0	12.1	51.1
RL	6.8	94.5	5.5	55.0

Values within a column having different letters are significantly different according to Tukey's test at $P < 0.05$. (CH = cocoa pod husk, CL= cocoa leaf litter, BF= banana fresh pseudo stem, BD = banana decaying pseudo stem, PF = fresh palm frond, PB = Palm empty fruit bunches, PI = male pale inflorescence and RL = rubber leaf litter.

The highest amount of ash was obtained from the decaying banana pseudostem (31.2%) followed by the male palm inflorescence (12,1%). This was obvious because the mineral elements which constitute the ashes increase with biomass decay. The ash content obtained for the different parts of oil palm in this study (6.3 – 12.2%) was on a whole higher than the results (9.3%) of Saka et al., 2008. This difference could be attributed to the difference in the soils from where the samples were collected.

Levels of total and available P, K and Mg and total Ca in plant residues

The release of nutrients from crop residues remaining after harvest is an important potential source of nutrients for crops (McLaughlin et al., 1988). Phosphorus which is a macro nutrient and very important for the energetic activities in plant ranged between 0.07% and 0.51% with the highest value obtained in palm male inflorescence and lowest in senescent cocoa and rubber leaves (Table 5). The highest value of phosphorus obtained in male palm inflorescence and cocoa pod husk corroborates the study of Nanaganoa and Njukeng (2018) who concluded their findings that cocoa pod husk and palm male inflorescence could be used as organic amendments, based on their high P content and release potential. The values of P, K and Mg obtained in this study were very close to the average values (respectively, 0.06, 2.03 and 0.19%) of different studies compiled by Nurul in 2015. With these nutrient values, the studied residues were considered as good nutrient sources. The level of total potassium and calcium were highest in the banana pseudo stem that had started decaying (BD). This sample also had the highest level of available K (8.8%) and this shows that K availability for crop uptake increases as the pseudo stem decays due to the breakdown of organic molecules. The lowest concentrations of total K were found in fresh palm fronds (PF) and rubber leaf litter (RL).

Calcium and Magnesium are known as plant secondary nutrients which are needed in slightly lower amounts than the macro nutrients. The lowest total Ca and Mg levels were found in palm empty fruit bunches (PB); 0.16%

and 0.16% respectively. These values were very close to average values of 0.21% for Ca and 0.12% for Mg obtained in palm empty fruit bunches in Indonesia (Teh, 2016). On the other hand, the levels of total Ca and P obtained from cocoa pod husk in this study were lower that those obtained by Nortey, 2015 (respectively 0.81 and 0.44%). This difference could be attributed to the origin of the samples.

Table 5. Total and available element concentrations in plant residues (in% of dry matter)

Element	Ca (%)	K (%)		Mg (%)		P (%)	
	Total	Total	Available	Total	Available	Total	Available
CH	0.39g	4.60c	3.61c	0.38c	0.05e	0.15b	0.11b
CL	2.17b	0.73f	0.594e	0.95a	0.13c	0.073g	0.04cd
BF	1.36c	7.51b	5.56b	0.17e	0.05e	0.090d	0.05c
BD	2.47a	10.32a	8.81a	0.42c	0.04f	0.086de	0.03d
PF	0.97f	0.59fg	o.53e	0.20e	0.16b	0.118c	0.04cd
PB	0.16h	2.59e	1.56de	0.16e	0.08d	0.080ef	0.05cd
PI	1.04e	3.30d	2.66cd	0.70b	0.20a	0.51a	o.39a
RL	1.27d	0.50g	0.47e	0.28d	0.20a	0.077fg	0.05c

Values within a column having different letters are significantly different according to Tukey's test at $P < 0.05$. (CH = cocoa pod husk, CL= cocoa leaf litter, BF= banana fresh pseudo stem, BD = banana decaying pseudo stem, PF = fresh palm frond, PB = Palm empty fruit bunches, PI = male pale inflorescence and RL = rubber leaf litter.

Levels of total Cu, Fe, Mn, Ni and S in plant residues

Table 6 presents data for the micro elements obtained in the studied agricultural residues. The nutrient contents ranged from 10.09 – 43.69mg/kg for B, 9.06 – 61.13mg/kg for Cu, 97.32 – 1828.65mg/kg for Fe, 46.23 – 1717.54mg/kg for Mn, 1016.60 – 3319.18 mg/kg for S and 28.56 – 421.95mg/kg for Zn (Table 6). The copper level obtained in this study for cocoa pod husk was very close to 46.13mg/kg that was obtained by Bonvehi and Rossend in 1998 for cocoa pod husks from different countries. The Zn content in this study (72.37mg/kg) was almost doubled the amount obtained by Bonvehi and Rossend in 1998 while studying cocoa bean husk while the Fe content for this study was very low compared to what they obtained. The lowest levels of boron and copper (10.71mg/kg and 9.06mg/kg respectively) were found in palm frond (PF). The highest level of B (43.69 mg/kg) was found in senescent rubber leaves (RL) and the highest Cu level (61.1mg/kg) was found in senescent cocoa leaves (CL). Iron and manganese (respectively, 1828.65 and 1717.54 mg/kg) were highest in the decaying banana pseudo stem (BD) while the lowest level of Fe (97.32mg/kg) was found in cocoa pod husk and the lowest Mn (46.23mg/kg) was in palm empty fruit bunches (PB). Sulphur is a very important element especially in plant defence. Its highest level (3319.18mg/kg) was obtained in palm male inflorescence (PI) while the lowest level was found in palm empty fruit bunch (PB). Its highest value in male palm inflorescence could be attributed to its essential role in the synthesis of oils, especially in oil crops (Ahmad et al., 2007). Zinc was highest in fresh banana pseudo stem (BF) and its lowest value was obtained in palm fronds.

Table 6. Levels of total B, Cu, Fe, Mn, S and Zn in plant residues

element	B(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	S(mg/kg)	Zn(mg/kg)
CH	31.23c	46.13b	97.37f	121.37g	2262.00c	72.37d
CL	38.47b	61.13a	336.33e	1025.67c	2622.67b	212.00c
BF	12.10d	9.67e	866.00b	567.67e	1138.67g	243.67b
BD	38.27b	47.73b	1828.67a	1717.33a	1800.67e	422.00a
PF	10.73d	9.07e	622.00c	627.33d	1562.00f	28.57f
PB	12.10d	23.00d	112.20f	46.23h	1016.67h	30.17f
PI	28.87c	36.80c	100.67f	337.33f	3319.00a	45.43e
RL	43.67a	10.03e	543.00d	1047.67b	2093.33d	37.43ef

Values within a column having different letters are significantly different according to Tukey's test at $P < 0.05$. (CH = cocoa pod husk, CL= cocoa leaf litter, BF= banana fresh pseudostem, BD = banana decaying pseudostem, PF = fresh palm frond, PB = Palm empty fruit bunches, PI = male pale inflorescence and RL = rubber leaf litter.

Conclusion

Traditional methods allow crop wastes to decompose naturally in the farm to replenish soil nutrients or to act as an organic fertilizer. However, with heavy rains in the tropics most of the needed nutrients are washed away in runoffs. Thus, an understanding of their physicochemical properties could lead to methods that will greatly improve their fertilizer properties and use. On the other hand, the contribution of nutrients by crop residues has to be taken into account when calculating the fertiliser requirements of the subsequent season in order to achieve better resource utilisation, thereby reducing the risk of eutrophication and improving farm profits by reducing expenditure on fertiliser.

Our analyses of eight crop residue samples from cocoa, banana, oil palm and para rubber plantations showed that they indeed present a considerable source of essential plant nutrients. The results obtained for available P, K and Mg further demonstrated that a relevant share of the total nutrient contents could become available to plants in the form of compost or when allowed to rot in the fields. However, these crop residues varied significantly in their properties, and further investigations on their decomposition rates are necessary to confirm and supplement our results. Acidity was high in a few samples indicating the need for blending them with materials of pH above 7 to get substrate or manures with suitable pH values for crop growth. In order to use them for feed, supplementary studies on their dietary properties is needed. However, these residues present a great potential for diverse use.

Conflict of Interest

There is no conflict of interest

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