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EFFECTS OF RUMEN DIGESTA ON THE PHYSICO-CHEMICAL PROPERTIES OF SOIL IN NSUKKA, SOUTHEASTERN NIGERIA

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ABSTRACT
In tropical and subtropical areas, the importance of organic manure in improving soil physico-chemical properties and crop production for food security cannot be overemphasized. A study was conducted during 2012/2013 crop years, to investigate the effects of rumen digesta on the physical and chemical properties of soil in Nsukka, Enugu State, Nigeria. Soil samples were collected from Opi, Nsukka and treated to four rates of rumen digesta (viz. 0, 50, 100, and 150 gkg^{-1} soils). Physical and chemical properties of the soil were determined pre and post-experiment. The results obtained revealed that rumen digesta significantly ($p = 0.05$) increased the mean weight diameter (0.49 to 1.75 mm), aggregate stability (54.7% to 75.3%), soil pH (3.8 to 7.8), total nitrogen (0.01% to 0.02%), exchangeable sodium and potassium (0.22 to 4.39 cmolkg^{-1} for Na^+ and 0.30 to 4.31 cmolkg$^-$ for K^+), CEC (7.2 to 14.9 cmolkg^{-1}) and organic matter content (0.97% to 4.29%). It had no significant effect on the texture, micro-aggregate (measured as dispersion ratio), exchangeable calcium and magnesium content of the soils. The study found significant reduction in the exchangeable aluminum (1.5 to 0.0 cmolkg^{-1}) and hydrogen (3.7 to 2.2 cmolkg^{-1}) contents of the soils. Farmers can therefore improve the physical and chemical properties of soils by using rumen digesta as an alternative liming material.

Keywords: Rumen digesta, soil properties, fertilizer use, Nsukka-Nigeria

INTRODUCTION

The use of organic manures (especially ruminant dung, poultry droppings, household refuse and effluents) for crop production is an agelong agricultural practice among the subsistence farming communities in West African subregion (Lombin et al., 1991). In many developing countries like Nigeria, the likelihood of obtaining enough synthetic fertilizers to meet the food crop requirement of the teeming farming population is remote. The ever-increasing demand for food has intensified the quest for more production per unit area and for an increase product of land under arable cultivation. Farmers in the tropics and the subtropics have been forced to eliminate fallow periods and rely on synthetic fertilizers. These practices (reduction in fallow periods and increased use of synthetic fertilizers) have lead to the increment in land degradation and decline of crop productivity. Odu and Mba (1991) stated that inorganic fertilize supply nutrients alone, while organic manures not only supply nutrient elements through microbial activities but also help in improving the soil physico-chemical properties. The inventory of urban and industrial wastes in Nigeria, as compiled by Sridar (2006) showed that millions of tons of industrial, domestic and animal wastes so produced annually in the country are not effectively utilized whereas these wastes can be utilized effectively for agriculture. Evidences indicate that by judicious application of these wastes on agricultural field one could maintain a high level of soil fertility. Investigations on the possible use of organic wastes to improve the productivity of soils have been carried out (Agbim, 1981; Omaliko & Agbim, 1983; Mbagwu 1985; Omaliko 1985).

The use of organic wastes as biofertilizers has necessitated many studies aimed at evaluating the fertilizing value of these organic waste products (poultry dropping, cow dung, and sewage sludge and swine wastes) to ascertain their potentials in improving soil fertility. However there is little information available about the effect of rumen digesta on the physical and chemical properties of soils in the study area. Rumen digesta are water and the associated

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water from an abattoir emanating from the paunch content (rumen) of ruminant animals, they are part of organic wastes or manures. A total of 194 kg of solid (rumen/stomach) waste is generated daily in Nsukka abattoir (Nwanta et al., 2010), therefore it will be beneficial to study its effect on the physical and chemical properties of soils. The objective of the study therefore, was to determine the effects of rumen digesta on the physico-chemical properties of soils from Opi in Nsukka Local Government Area (L.G.A) of Enugu State, Nigeria.

MATERIALS AND METHOD

Study Area

The experiment was carried out at the greenhouse of the Faculty of Agriculture, University of Nigeria, Nsukka. The soil sample was collected from a farmer's field at Opi while the rumen digesta was collected from Ikpa abattoir in Nsukka, Enugu State. Nsukka is located at latitude $06^0$52N and longitude $07^0$24E on an altitude of approximately 400 m above sea level. Generally the climate of Nsukka is characterized by mean annual rainfall of about 1600 mm and mean annual evapotranspiration (ET) of about 1560 mm. The ET however exceeds total rainfall in most months of the year (Igwe, 2004).. Temperature is uniformly high throughout the year, with mean minimum and maximum annual values of 21^oC and 31^oC respectively. Rarely does temperature exceed 35^oc during the hottest months (Asadu, 1990; Obi and Salako, 1995).

Grassland vegetation is predominant in the study location which according to Mbagwu (1991) is within the forest-savanna transition vegetation zone. The area has an ustic soil moisture regime and the soil around are characterized as being well drained with very low total exchangeable base, cation exchange capacity(CEC) and base saturation (Asadu, 1990). The soil is deep, coarse textured and low in organic matter with perennial leaching problem (Igwe 2004). The soils mostly belong to the order of Ultisol and Vertisol.

Sample Collection

From a farmers' farm field (0.05 km^2) at Opi in Nsukka LGA of Enugu State, auger samples were collected at a depth of 0 – 30 cm from randomly selected positions. The samples were bulked to get composite samples and transported to the greenhouse. The soil samples were air dried and sieved through a 2mm mes and stored in 12 plastic containers (1564 cm^3) before amendments were applied. The rumen digesta was collected from the paunch content of cattles, from Ikpa-Nsukka abattoir, Enugu State and air dried.

Experimental Design

One kg of soil was measured into plastic containers and treated with the waste at the rates of 0, 50, 100, and 150 g. Experimental design was completely randomized design (CRD) and treatments were replicated 3 times resulting to a total of 12 potted soils The treated soil samples were kept moist with distilled water (200 ml daily) during the 5 weeks duration of the experiment. The soil samples were analyzed for physical and chemical properties before and after amendment, while the rumen digesta was analyzed for its chemical properties before application.

Laboratory Studies

The laboratory analysis was conducted at the Soil Science laboratory, Faculty of Agriculture, University of Nigeria, Nsukka. The physical properties analysed were as follows: particle size distribution was determined using the hydrometer method (Bouyoucos 1962), Dispersion ratio, and the water stable aggregate of the soils which were determined by wet – sieving method of Kemper and Rosenau (1986). Aggregate stability was calculated as thus;

$$\frac{weight\ of\ stable\ aggregate - weight\ of\ sand}{weight\ of\ sample - weight\ of\ sand} \times 100 \qquad - \quad - \quad \text{-eq (1)}$$

Chemical properties analysed were: soil pH determined using glass electrode pH meter in water in the ratio of 1:2.5 (Maclean, 1982), organic carbon content determined by wet dichromate acid oxidation method (Nelson and Sommers 1982); and organic matter by multiplying organic carbon by a factor of 1.724. Total nitrogen was determined by using kjeldahl apparatus (Bremner and Mulvaney 1982), Exchangeable base by ammonium acetate leaching and exchangeable acidity by titration (MaClean, 1982). The effective cation exchangeable capacity (ECEC) was determined by summation of exchangeable bases and exchangeable acidity.

Statistical analysis

All data collected were statistically analyzed using Genstat 9.2 edition

RESULTS AND DISCUSSION

The chemical properties of the rumen digesta are shown in Table 1. The pH is 8.0 (alkaline in character).

The physical and chemical properties of the soil before application of rumen digesta are shown in Table 2. The soil has sandy clay loam texture. The percentage water dispersible (WD) clay and silt is 10%. Chemically, the soil is highly acidic (pH 3.1) with low percentage organic carbon (0.54%) and total nitrogen contents (0.11%). Generally the values of exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) are low according to Mbagwu (1992).

Physical Properties

The results of the soil particle size distribution (PSD) at different rates of rumen digesta application are presented in Table 3. There were no significant differences (p=0.05) between the %clay, %silt, and %total sand content and textural class of the treated soils and the untreated soils.

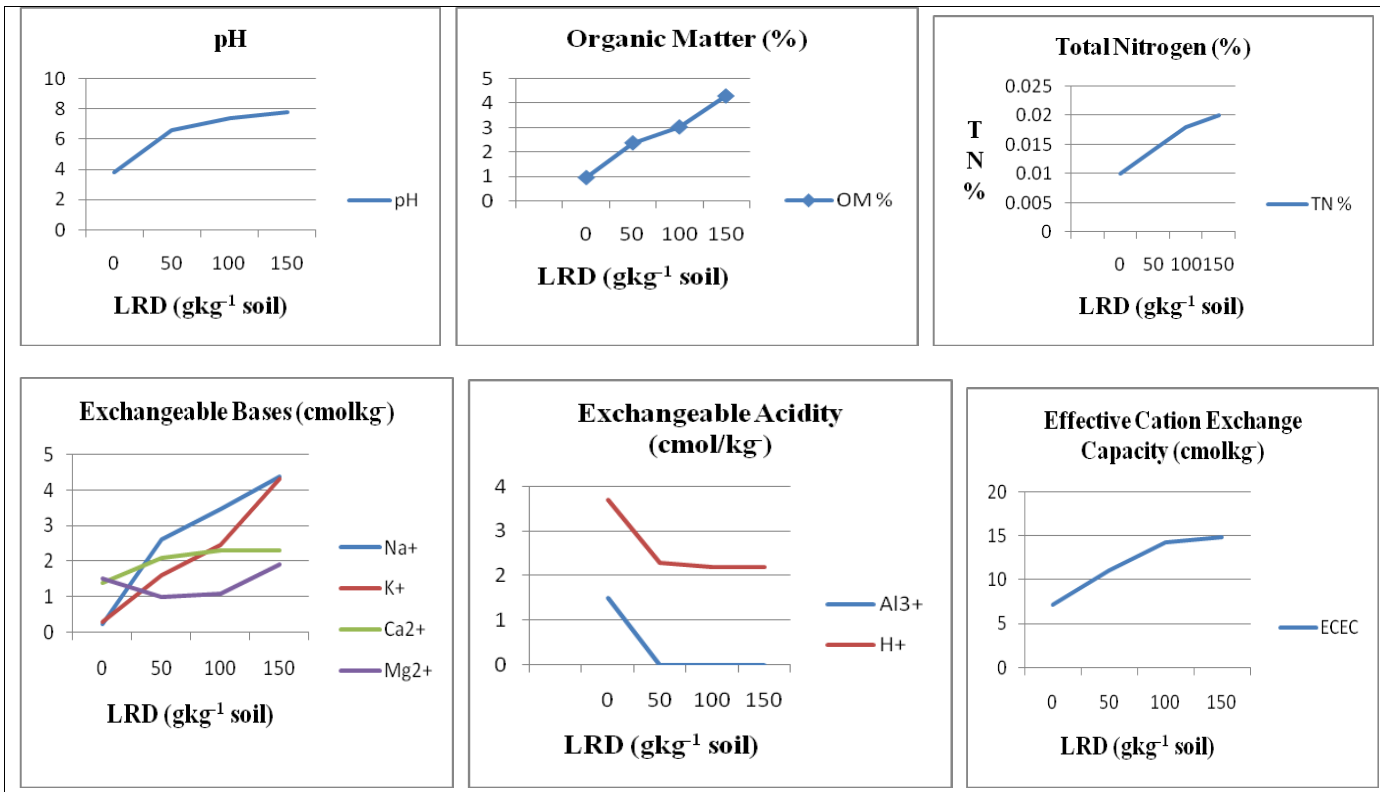

Fig 1: Effect of rumen digesta on the organic matter content, total nitrogen, exchangeable bases, exchangeable acidity and cation exchange capacity.
LRD = level of rumen digesta application

Table: 1 Chemical properties of rumen digesta (RD)

Parameter	Value
pH H_2O	8.0
OC %	28.15
TN %	0.023
Na^+ cmol/kg	24.21
K^+ cmol/kg	28.68
Ca^{2+} cmol/kg	3.2
Mg^{2+} cmol/kg	4.6
Al^{3+} cmol/kg	0.00
H^+ cmol/kg	33.46

OC = organic carbon, TN = total nitrogen.

Table 2: Initial soil analysis result

Parameters		Value
Physical properties	Clay (%)	20
	Silt (%)	4
	T. sand (%)	76
	Textural Class	Sandy Clay Loam
	WD Clay (%)	10
	WD Silt (%)	10
	DR	0.77
	CDR	0.5
	MWD (mm)	0.47
	AS (%)	53
Chemical properties	pH	3.1
	OC (%)	0.54
	OM (%)	0.93
	TN (%)	0.011
	Na^+ (cmol/kg)	0.22
	K^+(cmol/kg)	0.39
	Ca^{2+}(cmol/kg)	1.2
	Mg^{2+}(cmol/kg)	2.4
	Al^{3+}(cmol/kg)	0.8
	H^+(cmol/kg)	4.4
	CEC(cmol/kg)	6.4

T. sand = total sand, WD clay = water dispersible clay, WD silt = water dispersible silt, DR = Dispersion ratio, CDR = clay dispersion ratio, MWD = mean weight diameter, AS = aggregate stability, OC = organic carbon, OM = organic matter, TN = total nitrogen and CEC = cation exchange capacity.

Table 3: Particle size distribution of the soils of Opi-Nsukka

Rumen digesta (gkg^{-1} soil)	Clay	Silt	Total Sand	Textural Class
	→	%	←	
0	20	4	76	Sandy clay loam
50	21	5	74	Sandy clay loam
100	20	6	74	Sandy clay loam
150	19	5	76	Sandy clay loam
$LSD_{0.05}$	n.s	n.s	n.s	

In Table 4, there was no significant difference between the DR of the treated soils and the untreated soils. The DR of the untreated soil was 0.76 while that of the treated soils range from 0.75 to 0.84. This is similar to the result by Mbah and Onweramadu (2009) which showed that additions of soil organic amendments failed to significantly improve micro-aggregate stability (measured as dispersion ratio).

The soil weight at >2mm, 2-1mm, 1-0.5mm, 0.5-0.25mm and <0.25mm, mean-weight diameter and aggregate stability at different rates of rumen digesta application are presented in Table 5. Positive significant differences (p=0.05) in the weights of the soil, MWD and AS were recorded due to the application of rumen digesta. The variables increased as the rate of rumen digesta applied increased.

Table 5 shows the water-stable aggregate, mean-weight diameter and aggregate stability. There were significant differences (p=0.05) between the mean weight diameter (MWD) of the treated soils and the untreated soils. Rumen digesta significantly increased the mean weight diameter as the application rate increased. MWD value obtained at 150gkg^{-}soil was significantly higher than the control by 27.4%.

There was significant differences (p=0.05) between the aggregate stability (AS) of the treated soils and the untreated soils. Rumen digesta significantly increased the aggregate stability of the soils as the application rate increased. The AS of the untreated soil was 54% while the the treated soils ranged from 69.3 to 75.3%. This could be due to the binding power of organic matter on soil particles to form stable aggregates. This is in accordance with the research findings by Chaney and Swift (2006); El hadj et al. (2013); Nwite (2013); Mbah and Onweremadu (2009).

Table 4: Water-dispersible particle size distribution of the soils of Opi-Nsukka

Rumen digesta (gkg^{-1} soil)	WD Clay%	WD Silt %	DR	CDR
0	9	12	0.76	0.45
50	10	8	0.75	0.5
100	13	8	0.84	0.93
150	14	6	0.84	1.0
$L.S.D_{0.05}$	n.s	n.s	n.s	n.s

WD clay = water dispersible clay, WD silt = water dispersible silt, DR = Dispersion ratio, CDR = clay dispersion ratio.

Table 5: Percent water-stable aggregates, mean-weight diameter (MWD) and aggregate stability of the soils of Opi-Nsukka

Rumen digesta (gkg^{-1} soil)	>2	2-1	1-0.5	0.5-0.25	<0.25	MWD	AS %
			mm				
0	0.28	6.15	25.19	33.61	34.77	0.49	54.7
50	7.98	15.29	28.25	25.59	22.89	0.84	69.3
100	26.55	18.65	18.53	16.77	19.49	1.40	72.7
150	34.26	13.99	14.49	12.79	20.24	1.75	75.3
$LSD_{0.05}$	8.60	4.875	3.919	3.764	6.99	0.2816	6.54

MWD = mean weight diameter, AS = aggregate stability.

Chemical Properties

The soil pH in water, exchangeable bases (Ca, Mg, K, and Na), exchangeable acidity (Al and H), ECEC, total nitrogen, and organic matter at different rates of rumen digesta application are presented in Fig 1. As the rate of rumen digesta application increased the soil pH, exchangeable sodium (Na), exchangeable potassium (K), effective cation exchange capacity (ECEC), and organic matter content increased while the exchangeable acidity decreased.

From Figure 1 it was recorded that untreated soil had high soil acidity (pH = 3.8) while application at 50 g rumen digesta produced less acidic condition. At 150 LRD, soil pH appreciated by 15.4% relative to LRD at 50g, due to significant (p=0.05) increase in exchangeable cation contents in the soil colloidal complex. Low pH of 3.8 obtained with the application of rumen digesta at 0 and 6.6 with 50 gkg^{-1} soil might be associated to loss of exchangeable bases resulting from displacement reactions in the soil colloidal complex. Soil acidity has been blamed on excessive rainfall that necessitated eluviations and leaching losses of cations under field conditions. The rise in pH of the treated soils above 6 may have effect on the nutrient availability in the soil, because this is the pH range for maximum nutrient availability in the soils (Brady and Weil, 2005). The improvement of soil pH in the treated soils confirms the liming effect of rumen digesta. Similar reports on the liming effect of organic materials were shown by Duruigbo et al. (2006), Anon and Ubochi (2007), Okonkwo et al. (2009), Osemwota 2010 and Ekpe 2013.

Organic matter content of the untreated soil was 0.97% and ranged from 2.38% to 4.29% for treated soils. The organic matter content was highest in soils with treatment level of 150g/kg soil of rumen digesta. There were significant differences (p = 0.05) between the organic matter contents of untreated and treated soils. The increase in organic matter of the treated soils can be attributed to the increase in organic carbon and mineralization of the rumen digesta. This finding is in agreement with that of NRCS (1996) and Ekpe (2013) was noted that applying animal manure increases the supply of organic matter in the soil.

The total nitrogen content of the untreated soil was 0.010% but range from 0.014 to 0.020 for treated soils. The highest nitrogen content of treated soils of 0.020% was obtained from the application of 150g/kg soil of rumen digesta. This was significantly different (p=0.05) from the total nitrogen obtained from the control. Total nitrogen obtained from 150gkg^{-}soil LRD was higher than that of 100gkg^{-}soil, 50gkg^{-}soil and 0gkg^{-}soil LRD by 10%, 30% and 50% respectively. This resulted from the incorporation of rumen digesta to the soil and agrees with the findings of Awodun (2008) and Okonkwo et al. (2009) that mineralization of organic wastes results in the release of organic bound nutrients in the soil notably N, P and K. However, there were no significant differences between the total nitrogen obtained from the applications of 50, 100 g/kg soil rumen digesta and the control. Rumen digesta appeared to have influenced the total nitrogen content of the treated soils. However substantial amount of the nitrogen may have been lost through volatilization losses from the waste (Prasad and De Datta 1979).

All exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) had significant (p=0.05) increases in the soil with increase in treatment application (Fig 1), a suggestion that the organic amendment had effect on the measured soil parameters. Exchangeable K^+ increased by 93.0% in LRD 150 relative to LRD 0g. The values from LRD 50g to 150g were higher than the critical values of 0.16 to 0.20cmolkg$^-$ for crop production in the subtropical area (Isirima et al., as cited in Ezeaku, 2011). Findings are in agreement with what was reported by Osemwota (2010). The concentrations of the exchangeable cations in the treated soils improved; this shows that rumen digesta improved the exchangeable bases content in the soil. The increase in values may be as a result of increased soil pH which invariably has a liming effect on the soil and agrees with NRCS (1998) that increase in soil pH increases the availability of exchangeable bases. Increases in exchangeable bases due to application of organic residues have also been reported by Mbagwu (1992).

The untreated soil contained 1.5 cmol/kg of Al^{3+} but after amendment the Al content was significantly reduced to 0.0cmol/kg. The H^+ content of the untreated soil was significantly different from the H^+ content of the treated soils. Rumen digesta significantly reduced the H^+ content of the soils. The H^+ content of the untreated soils was 3.7cmol/kg, while that of the untreated soils were between 2.2 and 2.3cmol/kg. This also may have accounted for the increase in soil pH and reduction in acidity level. This result is in accordance with other works where organic manure reduced the Al^{3+} and H^+ content of the soil (Agboola and Odeyemi 1975; Charreau, 1975; Nwite; et al, 2012; Enueke; et al, 2013).

Effective cation exchange capacity contents in the treated soils were significantly different (p=0.05) from that of the untreated soils. The content of ECEC in the controls was 7.2cmol/kg while in the treated soils it varied from 11.1 to 14.9cmol/kg (Fig. 1). Therefore it could be said that rumen digesta significantly increased the ECEC of the soils. This result is similar to other reports that showed that organic matter increases the ECEC of the soil. Examples of such works were those conducted by Egawa (1975), Nwite (2012) and Asadu and Nweke (1999). This also is in agreement with NRCS (1996) that organic matter retains nutrients by providing cation and anion exchange capacities. For the soils of the tropics, values of ECEC between 6 and 8cmolkg^{-1-} is regarded as low, 8 to 11cmol kg$^-$ as medium and >12 cmolkg^{-1} as high (Enwezor *et al*. in Ezeaku, 2011). Based on these limits the amount of ECEC obtained in LRD 0 (control) and LRD 50 g was low and medium, respectively. The values obtained at LRD 100 and 150 g were high (Figure 1), indicating no response to N, P and K fertilization for crops in the tropical area (Ezeaku, 2011).

CONCLUSION

Results of the study revealed that rumen digesta significantly increased the mean-weight diameter (MWD), aggregate stability (AS), soil pH, total nitrogen (TN), exchangeable sodium (Na), exchangeable potassium (K), effective cation exchange capacity (ECEC) and organic matter content of the studied soil. Application of rumen digesta had no significant effect on the texture, exchangeable calcium (Ca) and exchangeable magnesium (Mg) contents of the soil. It significantly reduced the exchangeable aluminum (Al) and hydrogen (H) content of the soils.

For better sustainability of agricultural soils, 100 g of rumen digesta/kg soil is recommended to improve the physi-chemical properties of the soil of Opi since it gave the best results. Rates more than this would increase the soil pH to an alcidine level which would have a negative effect on crop productivity. This study recommends the use of rumen digesta as a form of liming material but with caution to avoid making the soil alkaline.

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