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Effects of rumen digesta on the physico-chemical properties of soils in Nsukka, Southeastern Nigeria

Ifeoma Gloria Edeh*, Charles Arinzechukwu Igwe and Peter Ikemefuna Ezeaku

Department of Soil Science and Land Resources Management, Faculty of Agriculture, University of Nigeria, Nsukka, 410001. Nigeria.

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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 to investigate the effects of rumen digesta on the physical and chemical properties of soils in Nsukka, Enugu State, Nigeria. The soil samples collected from Opi, Nsukka were treated with four rates of rumen digesta (viz. 0, 50, 100 and 150 g/kg soils). Physical and chemical properties of the soil were determined pre- and post-experiment. The results obtained reveal 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 cmol/kg for Na^+ and 0.30 cmol/kg to 4.31 for K^+), CEC (7.2 to 14.9 cmol/kg) and organic matter content (0.97 to 4.29%). It had no significant effect on the texture, micro-aggregate stability (measured as dispersion ratio), exchangeable calcium and magnesium content of the soils. The study found a significant reduction in the exchangeable aluminum (1.5 to 0.0 cmol/kg) and hydrogen content (3.7 to 2.2 cmol/kg) of the soils. It is recommended that farmers can improve the physical and chemical properties of soils by using rumen digesta as an alternative liming material.

Key words: Rumen digesta, soil properties, evaluation, rural land, Nsukka-Nigeria.

INTRODUCTION

The use of organic manures (especially ruminant dung, poultry droppings, household refuse and effluents) for crop production is an age-old agricultural practice among subsistence farming communities in the West African sub-region (Lombin et al., 1991). In many developing countries (for example Nigeria), the likelihood of obtaining enough synthetic fertilizers to meet the food crop requirements of the farming population is remote. The ever-increasing demand for food has intensified the quest for more production per unit area and for an increase in land under arable cultivation. Farmers in the tropics and the subtropics have been forced to eliminate fallow

*Corresponding author. E-mail: ifeoma.edeh@unn.edu.ng. Tel: 08036409764.

Abbreviations: Na, Sodium; **K,** exchangeable potassium; **ECEC,** effective cation exchange capacity; **MWD,** mean weight diameter; **AS,** aggregate stability; **TN,** total nitrogen.

periods and rely on synthetic fertilizers. These practices (reduction in fallow periods and increased use of synthetic fertilizers) have led to increased land degradation and declining crop productivity. Odu and Mba (1991) stated that inorganic fertilizers supply nutrients alone, while organic manures not only supply nutrients, but also help improve the soil physico-chemical properties through microbial activities. 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 produced annually are not effectively used, whereas they could be effectively used for agriculture. Evidence indicates that judicious application of these wastes on agricultural fields could maintain a high level of soil fertility. Investigations into the possible use of organic waste to improve the productivity of soils have been carried out by Agbim (1981); Anikwe (2000); Asadu and Igboka (2014); Hellal et al. (2014); Mbagwu (1985); Mbah, (2008); Nyamangara et al. (2001); Omaliko and Agbim (1983); Omaliko (1985).

Many studies have evaluated the fertilizer value of organic waste products (poultry dropping, cow dung, sewage sludge and swine wastes) and determined their potential for 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 part of abattoir organic wastes or manures, and are obtained from the paunch content (rumen) of ruminant animals. A total of 194 kg of solid (rumen/stomach) waste is generated daily in Nsukka abattoir (Nwanta et al., 2010). The objective of this study 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) in Enugu State.

MATERIALS AND METHODS

Study area

The experiment was carried out at the greenhouse of the Faculty of Agriculture, University of Nigeria, Nsukka. Nsukka is located by latitude 06°52 N and longitude 07°24 E at approximately 400 m above sea level. The climate of Nsukka is characterized by mean annual total rainfall of about 1600 mm and mean annual evapotranspiration (ET) of about 1560 mm, the ET exceeds total rainfall in most months of the year (Igwe, 2004). Rainfall distribution is characteristically biomodal, with peaks during July and October. The entire wet season lasts from April to October, whereas the dry season lasts from November to March. During the wet season, there is a soil moisture decline of 104 mm and a moisture surplus of about 260 mm which depletes to an average deficit of about 650 mm in the dry season (Mbagwu, 1987). Temperature is uniformly high throughout the year, with mean minimum and maximum annual values of 21 and 31°C, respectively. Temperatures rarely exceed 35°Cduring the hottest months (Asadu and Akamigbo, 1990; Obi and Salako, 1995). Grassland vegetation is predominant in the study location which is within the forest-savanna transition vegetation zone (Mbagwu, 1991). The area has an ustic soil moisture regime and the soils are described as being well-drained with very low total exchangeable base, cation exchange capacity (CEC) and base saturation (Asadu and Akamigbo, 1990. The soil is deep, coarse textured and low in organic matter with perennial leaching risks (Igwe, 2004). The soils mostly belong to the orders of Ultisols and Vertisols.

Sample collection

Auger soil samples were collected at a depth of 0 to 30 cm from randomly selected positions in farmer's fields (5 ha) at Opi, inNsukka LGA of Enugu State. The samples were bulked to form composite samples. The soil samples were air-dried and sieved through a 2 mm mesh and stored in 12 plastic containers (1564 cm^3) in the greenhouse before amendments were applied. The rumen digesta was collected from the paunch content of cattle, from Ikpa-Nsukka abattoir, Enugu State, and air dried. The soil type used for this experiment is a sandy clay loam ultisol.

Experimental design

The experiment was conducted during the months of April and May, 2014 and repeated at the same period in 2012. One kg of soil was measured into plastic containers and treated with different rates of air dried rumen digesta (0, 50, 100, and 150 g). Experimental design was completely randomized design (CRD) and treatments were replicated 3 times giving a total of 12 samples. The treated soil samples were kept moist with distilled water (200 ml daily) during the 5 week duration of the experiment. The quantity of water applied corresponds to actual quantity of rainfall in the field during 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:

i. Particle size distribution, determined using the hydrometer method (Bouyoucos, 1962)
ii. Dispersion ratio, clay dispersion ratio and water stable aggregation, determined by wet–sieving method of Kemper and Rosenau (1986). Aggregate stability was calculated as:

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

Chemical properties analysed were:

i. Soil pH, determined using glass electrode pH meter in water in the ratio of 1:2.5 (Maclean, 1982).
ii. Organic carbon content, determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982).
iii. Total nitrogen, determined using Kjeldahl apparatus (Bremner and Mulvaney, 1982).
iv. Exchangeable base, determined by ammonium acetate leaching.
v. Exchangeable acidity by titration (MaClean, 1982).
vi. Effective cation exchangeable capacity (ECEC), determined by summation of exchangeable bases and exchangeable acidity.

Statistical analysis

All data collected were statistically analyzed using Genstat 9.2 edition. A t-test was used to verify whether there were statistically

Table 1. Chemical properties of dry weight 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.

Parameter		Value
Physical properties	Clay (%)	20
	Silt (%)	4
	Total 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

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; CEC = cation exchange capacity.

significant differences ($LSD_{0.05}$) according to Steel and Torrie (1980).

RESULTS

The chemical properties of the rumen digesta are shown in Table 1. The pH value was 8.0 and alkaline in character. The physical and chemical properties of the soil before application of rumen digesta are presented in Table 2. The soil has sandy clay loam texture. The percentage of water dispersible (WD) clay and silt is 10%. Chemically, the soil is highly acidic (pH 3.1) with a low percentage of organic carbon (0.54%) and total nitrogen content (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. The results show that 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. The water-dispersible particle size distribution, dispersion ratio and clay dispersion ratio at different rates of rumen digesta application are presented in Table 4. There was no significant difference between the DR of the treated (0.76) and untreated (0.75 to 0.84) soils. The soil weight at >2, 2 to 1, 1 to 0.5, 0.5 to 0.25 and < 0.25 mm, mean weight diameter and aggregate stability at different rates of rumen digesta application are shown in Table 5. There were significant differences (p=0.05) between the mean weight diameter (MWD) of the treated and untreated soils.

Chemical properties

The soil pH in water, exchangeable acidity (Al and H), exchangeable bases (Ca, Mg, K, and Na), ECEC, total nitrogen, and organic matter at different rates of rumen digesta application are presented in Figure 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. The result shows that untreated soil had high acidity (pH = 3.8) while application at 50 g rumen digesta gave a pH of 6.6 (Figure 1). At application rate of 150 g/kg, soil pH increased by 15.4% relative to at 50 g/kg. There were significant differences (p = 0.05) between the organic matter contents of untreated and treated soils. Organic matter content of the untreated soil was 0.97% and ranged from 2.38 to 4.29% for treated soils (Figure 1). The organic matter content was highest in soils with a rumen digesta treatment level of 150 g/kg soil. The total nitrogen obtained in the untreated soil was significantly different (p=0.05) from that of treated soils. The total nitrogen content of the untreated soil was 0.010% but

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

Application rate (g/kg)	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	

n.s = Not significant.

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

Application rate (g/kg)	WD Clay %	WD Silt %	DR	CDR
0	9.0	12	0.89	0.47
50	9.7	12.3	0.85	0.48
100	10.3	11.3	0.72	0.47
150	10.0	10.3	0.72	0.50
$LSD_{0.05}$	1.331	2.491	0.0182	0.038
SD	0.577	1.080	0.0463	0.0645

WD clay = Water dispersible clay; WD silt = water dispersible silt; DR = dispersion ratio; CDR = clay dispersion ratio; SD = standard deviation.

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

Application rate (g/Kg)	>2 mm	2-1 mm	1-0.5 mm	0.5-0.25 mm	<0.25 mm	MWD (mm)	AS (%)
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
SD	3.73	2.114	1.699	1.632	3.03	0.1221	2.84

MWD = Mean weight diameter; AS = aggregate stability; LSD = least significant difference; SD = standard deviation.

ranged from 0.014 to 0.020 for treated soils. The highest nitrogen content (0.020%) of treated soils was obtained from the application of 150 g/kg of rumen digesta and it was higher than that of 100, 50 and 0 g/kgby 10, 30 and 50%, respectively. 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. Exchangeable cations in the soil (Ca^{2+}, K^+ and Na^+) apart from Mg^{2+} increased significantly (p=0.05) with increases in treatment application rate (Figure 1). Mg^{2+} content at application rates of 0, 50 and 100 g/kg were not significantly different (p=0.05) but was significantly different (p=0.05) from that of the control at 150 g/kg Mg^{2+} content. Exchangeable K^+ increased by 93.0% in application rate of 150 g/kg relative to that of 0 g/kg. The untreated soil contained 1.5 cmol/kg of Al^{3+} but after amendment the Al^{3+} content was significantly reduced to 0.0 cmol/kg (Figure 1). Rumen digesta significantly reduced the H^+ content of the soils. The H^+ content of the untreated soils was 3.7 cmol/kg, while that of the treated soils were between 2.2 and 2.3 cmol/kg. Effective cation exchange capacity in the treated soils was significantly different (p=0.05) from that of the untreated soil. The ECEC in the controls was 7.2 cmol/kg while in the treated soils it varied from 11.1 to 14.9 cmol/kg (Figure 1).

DISCUSSION

The texture of the soils was determined before and after treatment with rumen digesta. Rumen digesta had no effect on the sandy clay loam texture of the soil (Table 3).

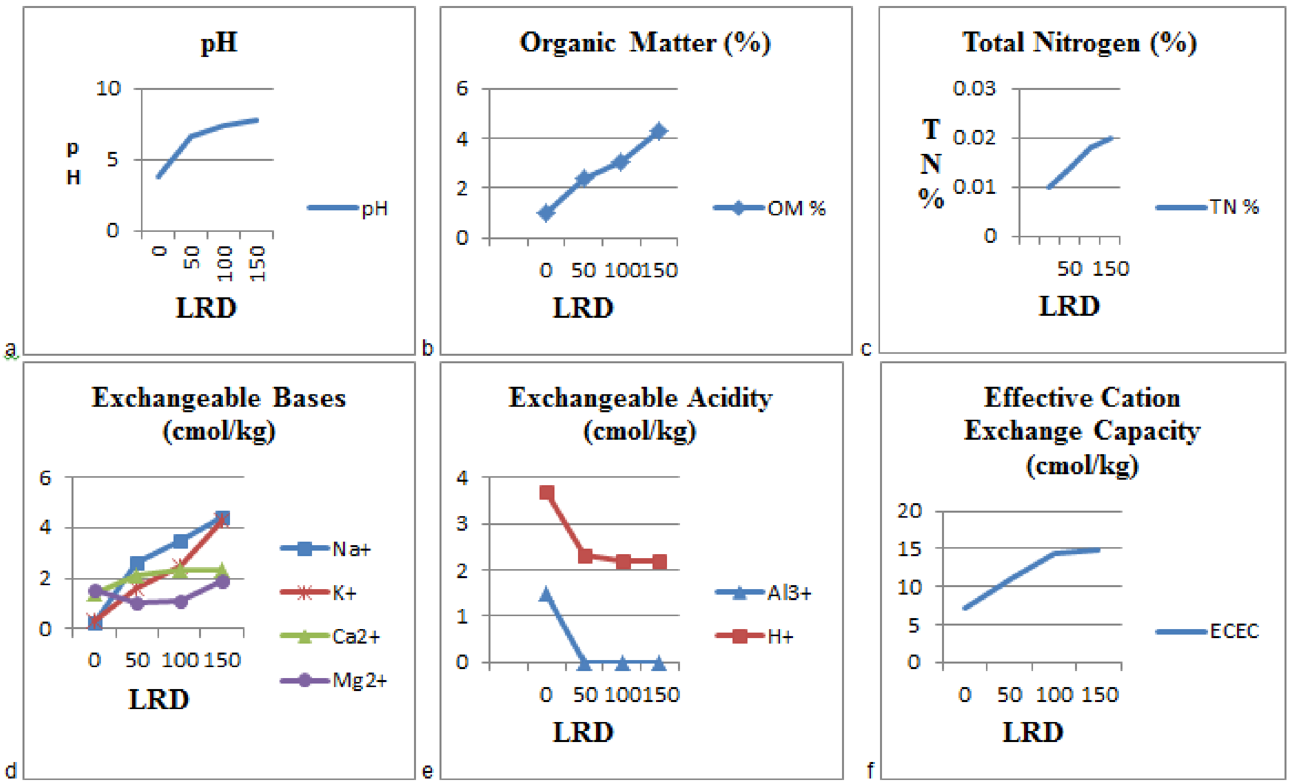

Figure 1. Effect of rumen digesta on the soil pH (a), organic matter content (b), total nitrogen (c), exchangeable bases (d), exchangeable acidity (e) and cation exchange capacity (f).

This could be due to the fact that texture is believed to be a fixed property. The non-significant difference between the DR of treated and untreated soils in Table 4 is similar to the result obtained by Mbah and Onweramadu (2009) which states that addition of soil organic amendments failed to significantly improve micro-aggregation (measured as dispersion ratio). In Table 5 there were significant differences (p=0.05) between the mean weight diameter (MWD) of the treated and untreated soils, especially at higher rate (150 g/kg) of rumen digesta application. The changes in water-stable aggregate, mean-weight diameter and aggregate stability could be due to application of the rumen digests. The results also show that there were significant (p=0.05) increases of the aggregate stability (AS) of the treated soils when compared to untreated soils at higher rates of rumen digesta application. This is probably due to the binding power of organic matter on soil particles to form stable aggregates. This result accords the research findings by Chaney and Swift (2006), El Hadj et al. (2013), Mbah and Onweremadu (2009) and Nwite (2013).

The results in Figure 1 show that application at rumen digesta at different rates correspondingly increased soil pH. This could be associated to a significant (p=0.05) increase in exchangeable cation contents in the soil colloidal complex. Low pH of 3.8 and 6.6 obtained in application rates of 0 and 50 g/kg might be associated with the loss of exchangeable bases resulting from displacement reactions in the soil colloidal complex. Soil acidity has been blamed on excessive rainfall that causes eluviation and leaching losses of cations under field conditions. The rise in pH of the treated soils above 6 may have an effect on nutrient availability in the soil. A pH range of 6 to 7 is generally most favourable for plant growth because most plant nutrients are readily available in this range (NRCS, 1998). 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 Anon and Ubochi (2007); Duruigbo et al. (2006); Ekpe (2013); Okonkwo et al. (2009); Osemwota (2010). The application of rumen digesta at the rate of 150 g/kg soil gave the highest organic matter content relative to untreated soils (control). 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 Ekpe (2013) and NRCS (1996) who noted that applying animal manure increases the supply of organic matter in the soil. The total nitrogen content of the untreated soil was found significantly different from that of treated soils. The highest nitrogen content of treated soils was obtained from the application of 150 g/kg of rumen digesta.

These findings are in agreement with that of Awodun

(2008) and Okonkwo et al. (2009) who noted that mineralization of organic wastes results in the release of organic bound nutrients in the soil notably N.P.K. Differences between the total nitrogen obtained from the applications of 50, 100 g/kg soil rumen digesta and the control were not significant. This may be related to the lower quantity of nitrogen at these application rates that can easily volatilize. A report by Prasad and De Datta (1979) had shown that a pungent smell emanating from organic waste indicate loss insubstantial amount of nitrogen through volatilization. Significant increase in exchangeable cations (Ca^{2+}, K^{+}, and Na^{+}) of the soil apart from Mg^{2+} due to increases in treatment application rates (Figure 1), suggest that rumen digesta improved the exchangeable base contents in the soil. The values of exchangeable cations from application rates of 50 to 150 g/kg being higher than the critical values of 0.16 to 0.20 cmol/kg implies that they may not be limiting crop production in the subtropical area (Isirima et al., 2003; as cited in Ezeaku, 2011). Findings are in agreement with those reported by Osemwota (2010). The increases in values may be as a result of increased soil pH, which invariably has a liming effect on the soil. NRCS (1998) noted 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 application of rumen digesta significantly reduced the exchangeable acidity of the treated soils when compared to untreated soils. This result is in accordance with other works where organic manure reduced the Al^{3+} and H^{+} content of the soil (Agboola and Odeyemi, 1972; Charreau, 1975; Enueke et al., 2013; Nwite et al., 2012).

Effective cation exchange capacity in the treated soils was found significantly different (p=0.05) from that of the untreated soil (Figure 1). This result is similar to other reports (Asadu and Nweke, 1999; Egawa, 1975; Nwite et al., 2012) that showed increases in ECEC of the soil due to increase in organic matter content. This is also in agreement with NRCS (1996) which noted that organic matter retains nutrients by providing cation and anion exchange capacities. For the soils of the tropics, values of ECEC between 6 and 8 cmol/kg was regarded as low, 8 and 11 cmol/kg as medium and >12 cmol/kg as high (Enwezor et al., 1990;cited in Ezeaku, 2011). Based on these limits, the ECEC obtained in application rates of 0 g/kg (control) and 50 g/kg was low and medium, respectively (Figure 1). The values obtained at application rates of 100 and 150 g/kg were high, suggesting that higher application of rumen digesta in the soil would significantly improve the effective cation exchange capacity of the soil.

Conclusion

Results of the study reveal 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 a soil. It had no significant effect on the texture, exchangeable calcium (Ca) and exchangeable magnesium (Mg) content of the soil, although it significantly reduced the exchangeable aluminum (Al) and hydrogen (H) content. Rumen digesta is a source of organic manure. For improved soil sustainability and crop productivity, it is recommended that 100 g of rumen digesta/kg soil should be applied to improve the physico-chemical properties of the soils of Opi. This level gave the best results, and at levels higher than this, the soil would become alkaline/saline, which would have a negative effect on both the soil and crop productivity. Rumen digesta is not always available in the sufficient amount of quantity needed by the large scale farmers; therefore a complementary use of rumen digesta and inorganic fertilizers is recommended. This study also recommends the optimal use of rumen digesta as a form of liming material, but with caution to avoid making the soil too alkaline.

Conflict of interests

The authors did not declare any conflict of interest.

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