Effect of Heat Treatment on Phosphate Sorption by Soils from Different Ecologies

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Abstract: This research project investigated the effect of heat treatment on phosphate sorption by soil collected from different ecologies in Nigeria. Selected physicochemical properties of the soil were analysed while the soils were heat to 40^0C and 100^0C respectively in the oven. Known phosphorus concentrations of 5, 10, 15, 20, and 25mg/kg using Sokoto Rock minerals were prepared and used for the sorption experiment including the soils at ambient temperature of 25^0C. The results of the physicochemical analysis showed that the soils were generally acidic (pH = 4.3 – 6.5) while organic carbon varied between 0.74 and 1.93%. The soils had clay content of 5.30 – 16.68%, while the cat ion exchange capacity was between 5.07 and 6.26cmol/kg. The sorption result shows that at 25^0C soil from Kaduna 1 in Kaduna State had the lowest Langmuir sorption maximum(Xm), at 40^0C, the lowest Xm value was obtained from Ubiaja in Edo State and also at 100^0C, soils from Kaduna 1 in Kaduna State had the lowest Xm value. This implies that the lower the Xm value and increase in temperature, the higher the concentration of phosphorus adsorbed. The result from this study can be used in planning for the application of phosphorus to soils from the different locations especially for improved soil fertility.

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Introduction

Phosphorus occurs in soil and it is an important nutrient. Application of phosphate (P) as solid or liquid fertilizer to soils leads to reactions with various soil components which remove P from the solution phase and convert it to less soluble phosphate. This process is known as P-retention. Surface sorption and surface precipitation are the two chief mechanisms which are used to describe P-retention (Sample et al., 1980). Phosphate sorption by soil minerals may be responsible for the removal of phosphate from more dilute phosphate solution.

Phosphate sorption is commonly measured by shaking samples of the soil with phosphate solutions, measuring the change against the observed solution concentration and then summarizing the result. The amount of P nutrient released to soil may be affected by different factors such as climate change i.e increase in temperature and global warming, and these can lead to reduction in crop production.

High temperatures are known to enhance the rates of phosphate sorption and desorption (Low and Black, 1959; Muljadi et al., 1966; Gardiner and Jones, 1973; Barrow and Shaw, 1975; Barrow, 1979; Aduloju and Olaniran, 2001). High temperatures lead to an increase in phosphate sorption and hence reduce phosphorus availability to plant. This work is aimed at accessing the release and retention of phosphorus following the application of heat to some soils equilibrated with rock phosphate solution.

Experiment

Soil samples used were obtained from Nigeria Institute For Oil Palm Research, NIFOR main station, Benin City, NIFOR substation Abak, Akwa Ibom State, NIFOR experimental station Ubiaja, Edo State and soils from Kaduna South Kaduna State. The soils were separated into two portions. A portion was processed for selected soil physico-chemical parameters and the second portion was heat treated at 40^0C and 100^0C.

Determination of physico-chemical properties of soil

The pH of the soils was determined by using the glass electrode pH meter.

The soil particle size was determined by the Bouyoucos (1962) method.

Organic carbon of the soil was determined by the Walkey and Black (1934). Chromate wet oxidation method.

Available Phosphorus was determined by Bray and Kurtz (1945) No.1 method.

Cation exchange capacity (Na, K, Ca, Mg), of the soil was determined by extracting the cation with

1M- ammonium acetate (1M NH_4OAc) buffered at pH 7.

Total Nitrogen of the soil was also determined by using the modified Kjedahl method (Juo, 1979).

Phosphorus stock solution

4.4g of Potassium dihydrogen phosphate (KH_2PO_4) was weighed and dissolved in 1L of distilled water to make 1000ppm stock solution. 10mls of this stock solution was put into 100ml flask and make up to mark with distilled water. This 100ppm solution was used to prepare the various concentrations taking 0, 2, 4, 6, 8 and 10mls by serial dilution for the phosphate sorption studies in 100ml volumetric flask to make 0,2,4,6,8 and 10ppm

Heat treatment

Each soil sample was subjected to heat treatments of 40^0C and 100^0C by keeping the weighed samples in labelled ceramic crucibles in an oven for two hours. In the control, the samples were not subjected to any heat treatment before they were used for the phosphate sorption studies. Each treatment was replicated three times.

Phosphorus sorption studies

Fifteen 1g-soil samples were weighed into sample tubes from each soil treated 25^0C (control), 40^0C and 100^0C respectively. 2ml, 4ml, 6ml,8ml and 10ml of the stock rock phosphate solution was put in a plastic tube. 0.01M $CaCl_2$ was used to make up to 30ml volume. The tubes were shaken for one hour the first day and 30 minutes each day for the next five days. Equilibrium was assumed to have taken place by the sixth day. On the seventh day, the contents of the tubes were filtered through Whatman No. 42 filter paper. The P content in the clear solution was determined by the Molybdenum blue method (Murphy and Riley, 1962). The differences in the amount of P added and that recovered in solution was considered the adsorbed P.

The data obtained from the phosphate adsorption experiment was fitted to the linear form of the Langmuir isotherms.

Results and discussion

The results of the study are presented as follows:

Table 3.1 shows the physiochemical properties of the soils, while Table 3.2 to 3.4 represents phosphorus sorption characteristics of the soils at 25^0C, 40^0C and 100^0C respectively, indicating the Longmuir sorption maximum (X_m), K the constant relating to bonding energy and R^2 the coefficient of regression. Furthermore, figures 3.1 to 3.15 shows the plots of Adsorbed versus Equilibrium P at the various temperatures (25^0C, 40^0C and 100^0C) of the soils from the five different location.

The physiochemical properties of the soil indicate that the soils were generally acidic with pH ranging between 4.4 and 6.3. Total organic carbon and total nitrogen were highest, 1.93% and 0.38% respectively in soil obtained from NIFOR main station, Benin. Similarly, the cation exchange capacity was between 5.07cmol/kg for soils from Akwa Ibom to 6.26cmol/kg for soils from NIFOR, Benin.

The soil texture indicates that soils from Kaduna 1 and Kaduna 2 had the highest clay content of 16.68% and 14.98% respectively. The soil from Abak, Akwa Ibom State had the lowest clay content of 5.30%. The amount of clay content in soil determines to significant extent the adsorption capacity of the soil (Ghanbari et al; 2000, Muljudi et al, 1966). The available phosphorus content of the soils ranged between 4.13 and 12.83mg/kg. However, low levels of phosphorus were expressed in soils from Kaduna 1 and Kaduna 2 respectively.

The phosphorus sorption characteristics of the soils at 25^0C are also shown in Table 3.2 and figure 3.1 – 3.5. It was observed that soils from Kaduna 1 (fig. 3.3) had the lowest Longmuir sorption maximum, X_m (0.2766) corresponding to the coefficient of regression (0.8149) indicating high adsorption of phosphorus at 25^0C. This was closely followed by the soil from Ubiaja, Edo State (fig 2) with X_m value of 0.2904 and R^2=0.9185. Soils from NIFOR, Benin had the highest sorption maximum, X_m (0.5851) value indicating that this soil released more available phosphorus is solution at 25^0C (fig. 1).

At 40^0C (Table 3.3 and figure 3.6 – 3.10), the highest X_m value was 0.5319mg/kg and the corresponding K value relating to bonding energy was 2.4894. This was obtained in soils from Abak, Akwa Ibom State (fig. 9). Less available P of equilibrium P was obtained from this soil. The lowest X_m value (0.2944) was determined in soils from Ubiaja, Edo State. The implication of this is that at 40^{oc} the soil from Ubiaja retained or adsorbed higher amount of phosphorus relative to the other soils continuing at 100^{oc} (Table 34 and figures 3 11-3.15). Soil from Aliak, Akwa Ibom state had the highest Xm (0.5302 mg 1kg) value corresponding to K=O.4759 and R^2 = O.7158 implying that this soil adsorbed the lowest amount of P at 100^oC (Fg3.14). This was closely related to values determined for soils from Ubiaja, Edo State with Xm value of 0.3022 and K = -1.3268 (fig 12). The lowest Xm values of 0.2193 was determined in soil from Kaduna 1, Kaduna State. This implies that at 100^oC the soil of phosphorus relative to the other soils.

Considering the physicochemical properties of soils in general clay content has been implicated more in the adsorption of phosphorus in soil. As clay content increases, the P sorption capacity of a soil increases (Samadi, 2006). However, in the present work while soils from Ubiaja sorbed more pat 25^{0}C with clay amount of 6.50% soils from Kaduna I sorbed highest pat 40^{o}C and 100^{o}C respectively.

Furthermore, the soils from Kaduna I had the lowest PH of 4.4 while the soils from Ubiaja, Edo State has the highest pH of 6.3. Therefore, the soil PH and clay content are two important characteristics to be considered with respect to the effect of temperature on sorption of P.

The initial concentration of phosphorus in both soils shows that soils from Ubiaja, Edo State had higher amount (10.40mg/kg), compared with soils from Kaduna 1.

Higher sorption of P at 25^{o}C by soils from Ubiaja suggests that despite their low clay content, there were still available sites for adsorption.

Table 3.1: Selected physicochemical properties of the soils.

Sample Identity	PH	C%	N%	P mg/kg	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Sand%	Silt%	Silt%	CEC cmol/kg
Nifor, Benin, Edo State	5.8	1.93	0.38	12.83	0.15	0.18	3.17	2.76	89.50	4.80	5.70	6.26
Ubiaja, Edo State	6.3	1.81	0.29	10.40	0.11	0.13	3.12	2.45	90.30	3.20	6.50	5.81
Kaduna1, Kaduna State	4.4	0.82	0.03	5.20	0.38	0.14	4.04	0.56	68.24	15.68	16.68	5.12
Abak, Akwa Ibom State	4.9	1.25	0.21	15.89	0.15	0.10	2.93	1.89	87.50	7.20	5.30	5.07
Kaduna2, Kaduna State	4.6	0.74	0.02	4.73	0.32	0.12	4.21	0.62	66.94	18.08	14.98	5.27

Table 3.2: Phosphorus sorption characteristics of the soils at 25^{O}C indicating the Langmuir sorption maximum (X_m), K is a constant relating to bonding energy and R^2, the coefficient of regression

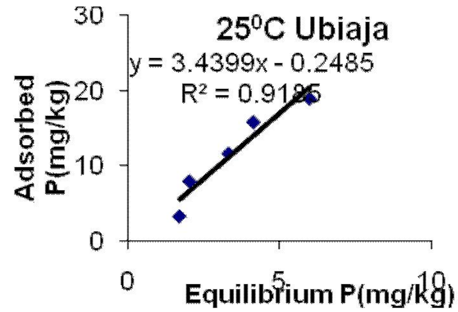
Sample Identity	$X_{m(mg/kg)}$	K	R^2
NIFOR, Benin, Edo State	0.5851	0.6516	0.8066
Ubiaja, Edo State	0.2907	-13.8504	0.9185
Kaduna, Kaduna State	0.2766	-2.2287	0.8149
Abak, Akwa Ibom State	0.3724	-0.9220	0.8036
Kaduna$_2$, Kaduna State	0.3590	-1.5691	0.8001

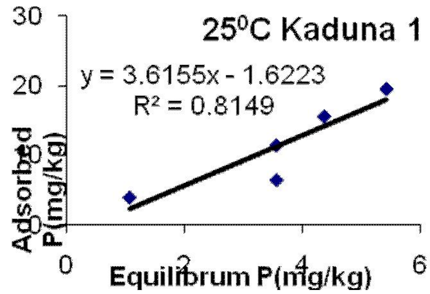
Table 3.3: Phosphorus sorption characteristics of the soils at 40^{O}C indicating the Langmuir sorption maximum (X_m), K is a constant relating to bonding energy and R^2, the coefficient of regression

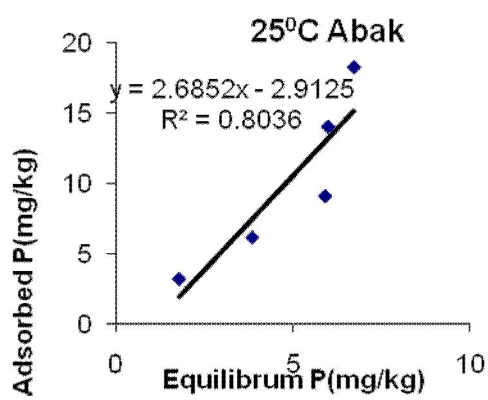
Sample Identity	$X_{m(mg/kg)}$	K	R^2
NIFOR, Benin, Edo State	0.5108	0.9710	0.9197
Ubiaja, Edo State	0.2944	-1.4787	0.9122
Kaduna, Kaduna State	0.3120	-1.1501	0.9163
Abak, Akwa Ibom State	0.5319	2.4894	0.9236
Kaduna$_2$, Kaduna State	0.5109	0.4271	0.5839

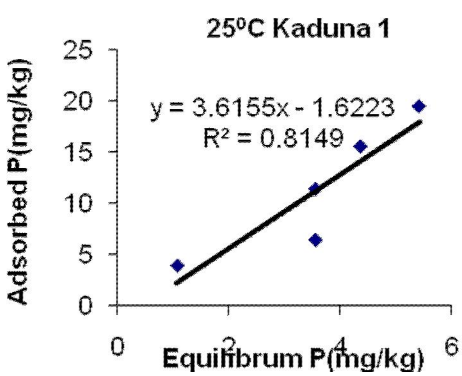
Table 3.4: Phosphorus sorption characteristics of the soils at 40^{O}C indicating the Langmuir sorption maximum (X_m), K is a constant relating to bonding energy and R^2, the coefficient of regression

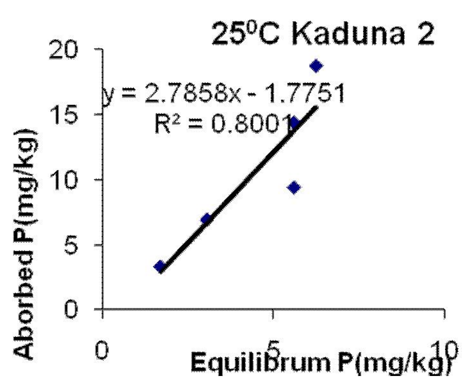
Sample Identity	$X_{m(mg/kg)}$	K	R^2
NIFOR, Benin, Edo State	0.4398	1.1906	0.8186
Ubiaja, Edo State	0.3022	-1.3268	0.9716
Kaduna, Kaduna State1	0.2193	-1.0453	0.9733
Abak, Akwa Ibom State	0.5302	0.4759	0.7158
Kaduna$_2$, Kaduna State2	0.4083	0.7743	0.6318

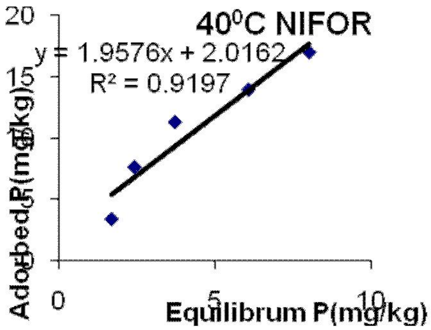


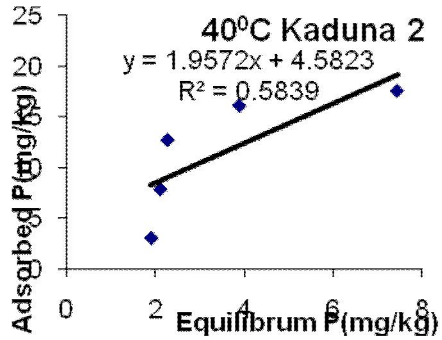


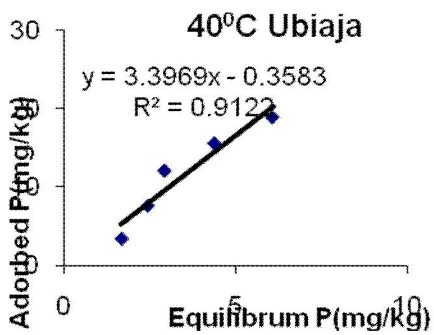


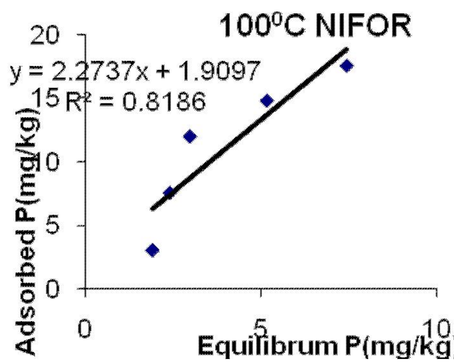


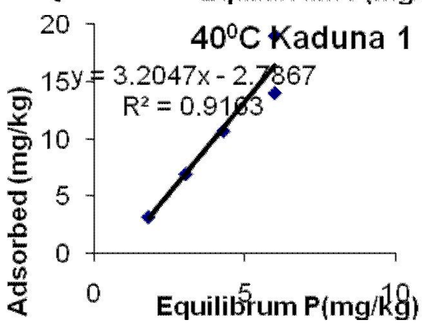


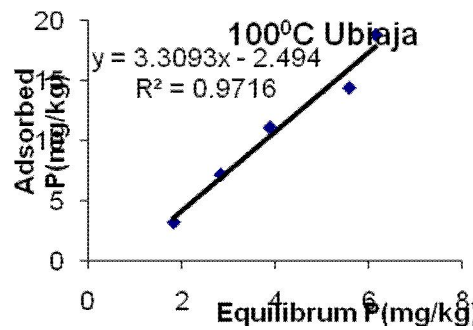

40⁰C NIFOR
y = 1.9576x + 2.0162
R² = 0.9197
Adorbed P(mg/kg)
Equilibrum P(mg/kg)

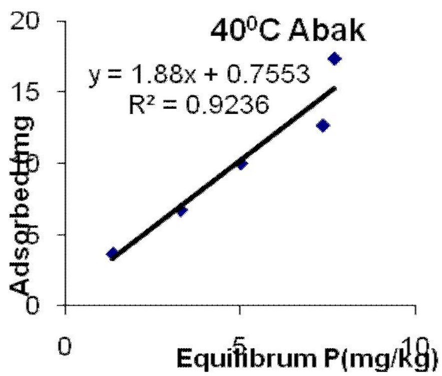

40⁰C Kaduna 2
y = 1.9572x + 4.5823
R² = 0.5839
Adsorbed P(mg/kg)
Equilibrum P(mg/kg)

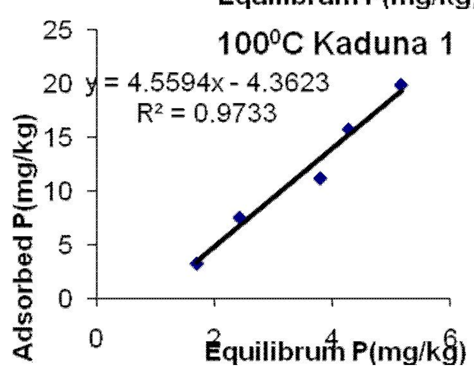

40⁰C Ubiaja
y = 3.3969x - 0.3583
R² = 0.9122
Adorbed P(mg/kg)
Equilibrum P(mg/kg)

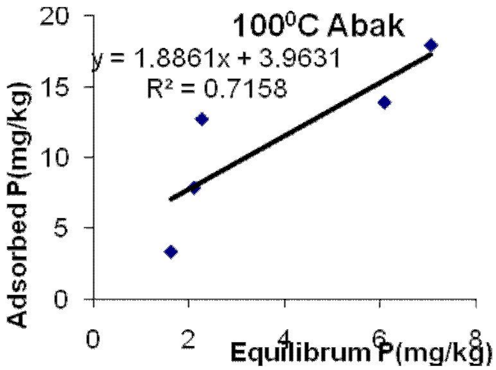

100⁰C NIFOR
y = 2.2737x + 1.9097
R² = 0.8186
Adsorbed P(mg/kg)
Equilibrum P(mg/kg)

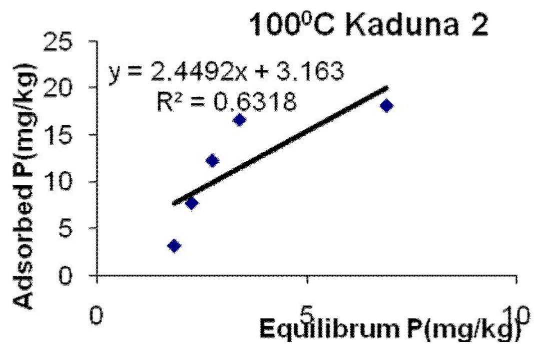

40⁰C Kaduna 1
y = 3.2047x - 2.7867
R² = 0.9163
Adsorbed (mg/kg)
Equilibrum P(mg/kg)


100⁰C Ubiaja
y = 3.3093x - 2.494
R² = 0.9716
Adsorbed P(mg/kg)
Equilibrum P(mg/kg)


40⁰C Abak
y = 1.88x + 0.7553
R² = 0.9236
Adsorbed mg
Equilibrum P(mg/kg)


100⁰C Kaduna 1
y = 4.5594x - 4.3623
R² = 0.9733
Adsorbed P(mg/kg)
Equilibrum P(mg/kg)





Conclusion

The study shows that increase in temperature has effect on the adsorption of phosphorus in soil depending on the soil properties. Within a particular soil type the effect is noticed at specific temperature range. For example, 25°C, soils from Ubiaja sorbed higher amounts of P while at 40°C the high clay content soil sorbed the highest P. The result from this study can be used in planning for the application of phosphorus to soils from the different locations especially for improved soil fertility.

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