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OPTIMIZATION OF OPERATING PARAMETERS IN THE EXTRACTION OF CAUSTIC POTASH (KOH) FROM PALM KERNEL BUNCH [AN AGRICULTURAL BY-PRODUCT] ASH

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Abstract

Extraction of potassium hydroxide from palm kernel bunch ash was carried out at various temperatures and times. This paper therefore highlights the effect of temperature and time on the yield of potassium hydroxide from palm kernel bunch. It further optimized these parameters called operating parameters to get the best-fitted combination of temperature and time that gives the maximum yield of potassium hydroxide. The various data were used to form an objective function, with yield as dependent variable. The temperatures and times were used as the independent variables. The most suitable equation was selected based on regression analysis and optimized using the one-at-a-time method. The result shows that the optimum yield was 33.78% at 630.76°C and 9 hours 9 minutes for temperature and ashing period respectively.

Introduction

Caustic potash is one of the most important materials which is used in many chemical industries, for the manufacture of explosives and gun powder. In it's converted form, it is used in producing potassium chloride, potassium sulphate, hard soap for shaving powder, rayon, treating wood pulp for making paper, cellophane and dyes. (George, 1984). The human mind can confront a task or problem and recognize more than one course of action. This recognition is followed by a second phase, the selection of what is considered the best action. The second phase is the decision step. These two steps taken together; recognition of alternatives and decision is what is called optimization. Optimization can be qualitative or quantitative, (Beightler *et al.*, 1979). There are basically three categories of optimization. The first is preferential; the second is mathematical or physical and lastly, is economic optimization, which is a combination of the previous, two. There are many ways of producing caustic potash in various chemical industries. It can be produced from industrial waste and mineral deposit. The paper looked at the production of caustic potash (KOH) from and agricultural product, palm kernel bunch. The word potash, is from the fact that extraction of wood ashes with water produces KOH – K_2CO_3 solution. Palm kernel bunch is an agricultural by-product and constitutes worldwide disposal problem (Akinosaye, 1976)

Optimization involves the determination of a highest or lowest value over a range. Thus a problem can be maximized for profit or minimized for loss (Beighter et al, 1979). Many methods have been introduced to determine optimum procedures but in practice there are three general methods. These are analytical, graphical or tabular and incremental methods. Analytical method involves finding derivative of a function. In graphical method, a plot of y against x over a feasible range yields all

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information for the optimization of y. Incremental method is operating at one value of the independent variable, changing the variable somewhat, and determine by calculation or observation whether the change is advantageous. Some mathematical techniques for multi variable optimization are; one – at – a-time method, steepest abscent or descent, constrained optimization and Lagrange Multiplier,(Friedman and Savage 1977).

An optimization problem is an exercise in mathematical modeling that requires great care in setting up the model; four steps are involved: (i) Decision of the exact objective to be optimized. (ii) Setting up the objective function using as many variables as are required. (iii) Setting up all the restraints and relationship between the variables. (iv) Reduction of the objective function to independent variables. George (1984) reported that Palm kernel bunch contains various organic and in-organic compounds, which are water (13%), fatty substances (5%), ash (free from SiO_2)(60%), total dry matter (20%) and nitrogen free extract (2%).

Experimentals

Treatment and Extraction of Palm Kernel Bunch

The palm kernel bunch was washed and dried using thermals radiation after which it was crushed for particle size reduction using pestle and mortar. The crushed sample was ashed in an oven at various temperatures of 300°C, 400°C, 500°C, 600°C and 700°C at different periods of 1, 2, and 3 hours respectively in a furnace. Direct leaching was used to extract the caustic potash from the ash using water as the solvent. It is an operation where some component of the solid phase can be separated by selectively dissolving the soluble part of the solid with an appropriate solvent. Usually the desirable component is soluble. The solvent was recovered by evaporation, leaving the caustic potash as residue. The yield was calculated at various ashing temperatures and periods. This was done by dividing the mass of the caustic potash after the extraction by the mass before extraction and multiplying by hundred. Least square method was used to obtained the equations forming the objective function. After which the best-fit equation was selected, and the optimization was performed using one –at – a - time method.

Results and Discussion

The results of the experiment show that at temperature of 300°C the yield of caustic potash increases with increase in time at 1,2 and 3h respectively. Same is applicable at temperatures 400°C, 500°C and 600°C. At temperature 700°C, there is a decrease in the yield of caustic potash thought the extraction time remain the same. The results obtained show that an increase in temperature gives a corresponding increase in yield up to temperature of 630.76°C, after which any increase shows a drop in the slope of the graph. That is, after the temperature of 630.76°C further increase in temperature produces a negative effect on the yield. This is because as the temperature of ashing increases, more of the organic and inorganic matter in the palm kernel bunch burnt off. Hence there is reduction in the mass of ash and consequently in the amount of potassium hydroxide (KOH) obtained (Hilmmelblau, 1996). Also it can be due to the fact that as temperature of ashing increases, more organic materials that interrupt the leaching process are being converted to water and carbon dioxide (Mc Cabe *et al*, 1993).

Table1. Various temperature and time with their corresponding yield of caustic potash

Run potash.	Temperature (°C)	Time (Hour)	Yield of Caustic (%)
1	300	1	2.60
2	300	2	4.51
3	300	3	5.21
4	400	1	7.99
5	400	2	11.79
6	400	3	14.65
7	500	1	12.34
8	500	2	12.34
9	500	3	21.10
10	600	1	26.88
11	600	2	27.89
12	600	3	29.59
13	700	1	14.26
14	700	2	16.08
15	700	2	16.66

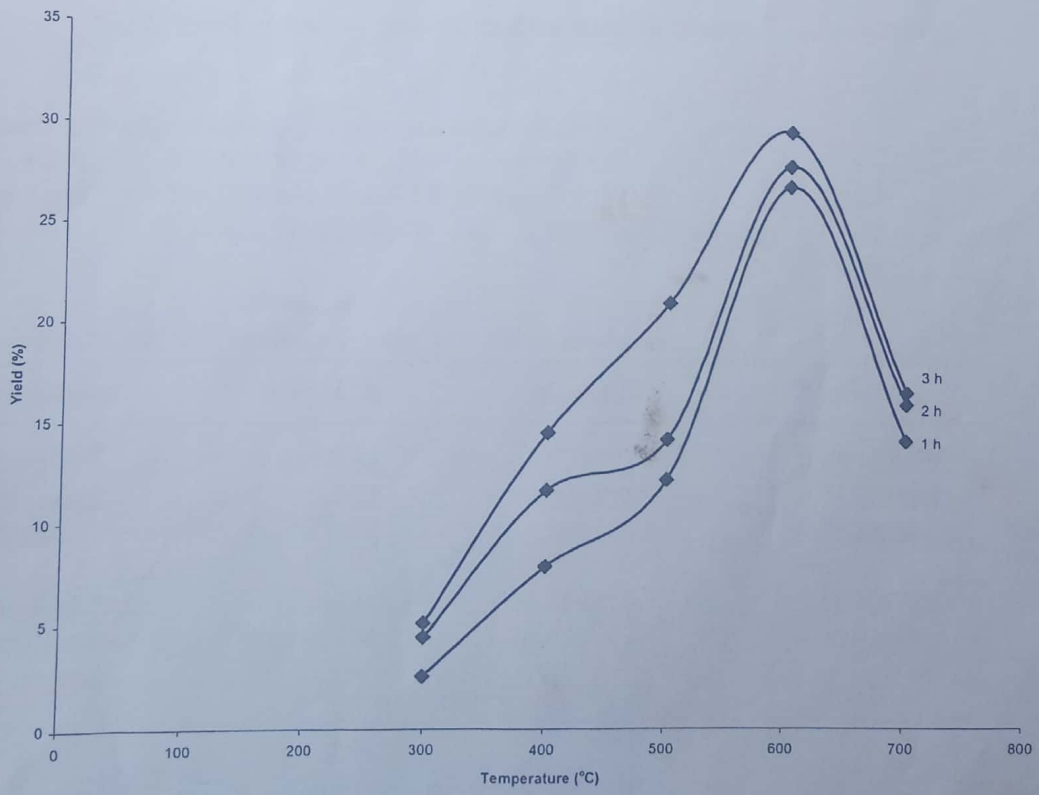

Fig 1. Yield of caustic potash against temperature at constant time

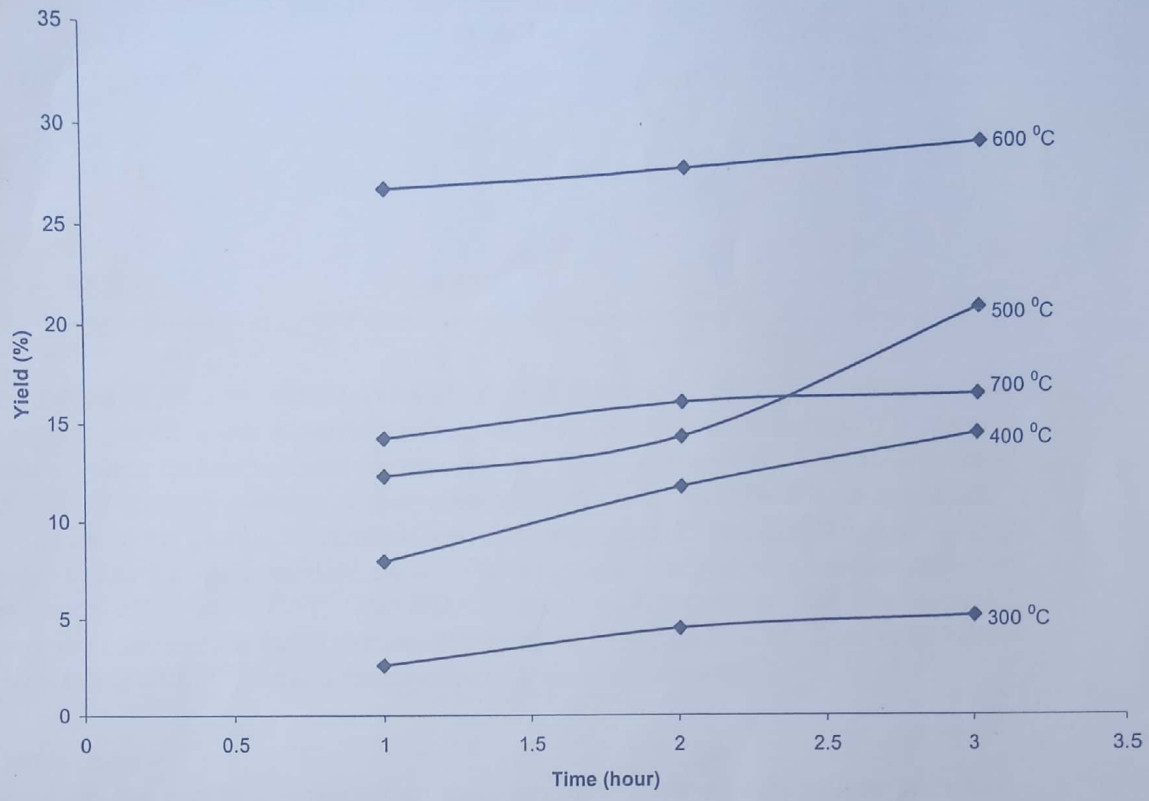

Fig 2. Yield of caustic potash against time at constant temperature

Table 3. Predicted models and their statistical analysis

Model A: $Y = 0.03976x_1 + 2.314x_2 - 9.45033$.....1.0

Model B: $Y = 0.0444133x_1 + 3.4065x_2 - 0.002185x_1x_2$ 2.0

Model C: $Y = -63.39+0.27x_1+2.56x_2 - 0.00023x_1^2 - 0.212x_2^2 + 0.0022x_1x_2$....3.0

Table 4. Statistical analysis for the predicted models

Regression	Model A	Model B	Model C
Multiple R	0.7307682	0.7314288	0.869329297
R Square	0.5340222	0.53449881	0.755733601
Adjusted R	0.4563592	0.4081667	0.762003005
Standard Error	6.1955678	6.464349	5.18015775
Significance F	0.0102374	0.0325477	0.0010414
Observation	15	15	15

Table 5. Interaction for one-at-a-time method

X_1 (°C)	X_2 (hour)	Yield of caustic potash (%)
591.78	1	19.49
629.82	8.959	33.76
630.73	9.149	33.77
630.75	9.154	33.78
630.76	9.154	33.78
630.76	9.154	33.78

This makes KOH more readily available for the extraction. Fig 2. shows that increase in ashing period gives a corresponding increase in yield until a time of 9 hours 9 minutes when further increase in time has no effect on the yield. This means that at the time of 9hours 9 minutes all the potassium hydroxide might have been exhausted.

From the graphs, three models were developed and from the statistical analysis model C has the least standard error. The regression analysis also has coefficient of regression (R^2) as 0.7557 (75.57%). Various analyses show that the optimum operating condition in the extraction of potassium hydroxide (KOH) from palm kernel bunch ash is 630.76°C with ashing period of 9 hours 9 minutes.

Conclusion

Based on the results obtained from the study the following conclusions are made: (i) Caustic potash (KOH) can be produced from palm kernel bunch, which is an agricultural by-product. (ii) Temperature and time have great effect on the yield of the caustic potash. (iii) The maximum combination of operating condition to give an optimum yield of 33.78% is 630.76°C at 9 hours 9 minutes.

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