Design of a Processor for the Production of 30,000 Tons of Caustic Potash per Anum from Cocoa Pod Husk

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Abstract: *A caustic potash processor capable of processing 30, 000 tons of caustic potash per anum from cocoa pod husk was designed. It essentially consist of storage tank, fluidized bed dryer, rotary dryer operating at a temperature of $110^0 C$ for drying the feed, roll crusher which reduces the husks into smaller sizes and a furnace operated an elevated temperature to ensure proper ashing. The processor also consists of a reactor where leaching: the major process involved in the production of caustic potash from cocoa pod husk takes place. The reactor is lagged and heated internally after which an evaporator fired by a boiler is employed to concentrate the KOH solution. The water vapour leaving the evaporator condenses in the condenser and is recycled to the boiler. A detailed energy and material balance as well as analysis of process control system and instrumentation was also carried out to keep process variable within known safe operating limits in order to achieve the designed production rate and maintain the caustic potash within the desired specification at an optimal production cost.*

Keywords: Ashing, Energy and material balance, Furnace, Husk, Lagging, Leaching

1. Introduction

The word "potash" comes from the fact that extraction of wood ashes with water produces potassium hydroxide or potassium carbonate solution. The cocoa pod husk is one of the essential by-products of cocoa making about 56% of the pod [1]. However, the missing link has been the development of a processor for processing cocoa pod husk to caustic potash. Unfortunately, in most West African countries producing commercial quantity of cocoa, the economic use of various by-products of cocoa has not been optimally harnessed. The indiscriminate dumping of cocoa pod waste in concentrated heaps on the farms has adverse effects on soil fertility [2], if prudently exploited it remains a potentially viable resource. Therefore, resources and energy derivation from crop farming in Nigeria is economically feasible without altering the food chain but the major challenge is the appropriate technology to convert waste to wealth. The exploitation of the wastes (cocoa pod husk) as a source of caustic potash will meet little or no problem in terms of raw material availability, besides, caustic potash gotten from cocoa pod husk is best useful as laboratory reagent and will also serve domestic and industrial purposes. In addition, many researchers have reported on the production of caustic potash via leaching, however, the analysis of integration features of the overall process for caustic potash production from single or multi locally sourced feedstock has been a missing link and process design issues have not always been sufficiently highlighted. These are areas of interest in this research work with a view of getting a comprehensive picture of the role of process design and engineering in caustic potash production processes from agricultural wastes.

2. Literature Review

The common alkalis used in soap making are sodium hydroxide (NaOH) also called caustic soda and potassium hydroxide (KOH) known as caustic potash [1][3]. One of the setbacks of cocoa production in Nigeria is the economic use for its various by-products being wasted. Over 30,000 tons of pod husk are wasted annually [4]. These by-products are the cocoa pod husk (about 56% of the pod), the sweetened scanty mucilage containing less of simple sugars (2%). Wood ash is about 25%, calcium carbonate and contains about 10% potash (K_20), 1% phosphate and trace amount of micro-nutrients [1]. Potassium hydroxide otherwise known as caustic potash, potash-lye, potassium hydrate or lye can be locally produced from agricultural wastes like wood [5], [6], coconut seed [7], orange peels, banana and plantain peels [8], [9], [10] cassava peels, livestock dung [11], kola nut pod husk, cocoa pod husk [12], palm kernel shell, sugar beet waste [13], maize cob [13], palm bunch waste [14], vegetable matters [2] [15], cashew nut shell [16] and many others. Cocoa has huge potential as an economical source of caustic potash [2]. Prudent exploitation of all these resources will enhance sustainability and will not only make our environment free of those agricultural wastes that often renders them untidy but will also save the environment from the harmful effect of pollution that commonly associate with the use of synthetic chemicals [14]. Also, alkalis derived from locally produced ash have been proved to be cheap alternatives to imported ones or synthetic chemicals [14]. Combustion of wood waste to ashes reduces the wood waste volume by 95% [17], hence plant waste could be disposed by combustion and the resulting ashes used for potash production [18] [19]. Potash yield depends on the type of plant material, the nature of soil where the plant grows and the efficiency of extraction technology [8]. A carbonate content of 40-60% and 3-5% based on the ash and dried husk respectively

confirmed that ash of cocoa husk contains a higher than average percentage of potassium carbonate [12].

The Chemical Compositions of cocoa pod husk is shown in Table 1.

Table 1: Chemical Compositions of Cocoa Pod Husk

S/N	Constituents of Cocoa pod Husk	% Composition of Constituents
1.	Water	57.75
2.	Total dry Matter	42.25
	Total	100
1.	Crude Protein	8.69
2.	Pure Protein	-
3.	Fatty Substance	0.15
4.	Ash (SIO, free)	10.80
5.	Crude Fibre	33.90
6.	Nitrogen-free extracts	41.21
	Glucose	1.16
8.	Sucrose	0.18
9.	Pectin	3.71
10	Theobromine	0.20

Source: [20]

Table 2: Physical Properties of KOH

Property	KOH solid (90%)	KOH aq. solution (50%)
Physical state	Solid	Liquid
Colour	White	Colourless
Density at 20^0C (g/cm^3)	2.044 (fused solid)	1.5
Melting temperature (^0C)	406	6
Boiling temperature (^0C)	1327	145
Molecular weight (g/mol)	56.1	

Source: [21]

Table 3: Weight of Extract and Caustic Potash Contents of Kola nuts Pod Husks, Ugwu Pod Husk and Plantain Peels Ashed at Different Temperatures

Temp (^0C)	Weight of Extract (g)			Caustic Potash Contents (g)		
	Kola	Ugwu	Plantain	Kola	Ugwu	Plantain
300	9.26	0.38	0.80	0.08	0.07	0.06
400	10.04	0.90	1.66	0.28	0.10	0.14
500	13.40	3.44	4.00	4.97	5.65	5.70

Source: [7]

2.1 Material Selection

1. Storage Tank

Liquid caustic potash can be suitably stored in mild steel tanks. It is generally non-corrosive to mild steel at ambient temperature, although it does pick up a very small amount of iron. For uses where iron impurity is undesirable, stainless steel tanks should be used. Aluminium, copper, bronze, brass, zinc etc. are readily attacked by caustic potash solution hence unsuitable for use as construction materials. Rubber lined tanks may also be used at ambient temperature as well as plastic tanks such as PVC (Poly vinyl chloride), polyethylene and polypropylene. Caustic potash is classified as hazardous chemical [8]; about 38% to 50% KOH can cause very serious and rapid burns to the skin and permanent injury to the eyes. It should therefore be handled with care by wearing appropriate clothing and equipment.

2. Rotary Dryer

A rotary dyer is suggested for this work because of the hollow shape of the cocoa pod husk so as to ensure even distribution of heat to the husk to enhance effective drying.

2.2 Process Description

Cocoa pod is stored in the storage tank. The stored cocoa pod is thereafter conveyed into the rotary dryer operating at a temperature of 110^0C after which the cocoa pod leaves the rotary dryer as bone-dried husk. Any impurity like leaves, stones etc on the husk would have dropped off at the base of the rotary dryer. The drying process is followed by sending the dried bone husk into the roll crusher to reduce the husk into smaller sizes (lump sizes) so as to increase the rate of ashing. Ashing of crushed husk take place in the furnace operated at an elevated temperature of 700^0C to ensure that the husk is properly ashed. The ashed husk are then gathered in a hopper from the furnace and allowed to cool before it is conveyed to the reactor so as to ensure that the temperature of the ash is kept low as it is fed into the reactor. The ash is conveyed into the reactor with the aid of a belt conveyor. The next line of action takes place in the reactor where leaching of potassium hydroxide (KOH) from the ash takes place. Water from the bore hole is sent into the adsorber to remove any ion present (anions and cations). Water then flows into the reservoir where it is stored and from where it flows into the reactor with the aid of a control valve. Inside the reactor, leaching process takes place, which is the removal of a soluble solute by means of a solvent from an insoluble solid. The KOH solution is then sent into the dilution tank to ensure that all moles of potassium ions present are dissolved. It is then filtered so as to extract the KOH solution from the residue. The residue is collected while the KOH solution is concentrated with the use of evaporator. This is achieved using a boiler attached to the evaporator which generates steam to power the evaporator. The KOH solution leaves the evaporator as concentrated liquor and the water vapour leaving the evaporator condenses in the condenser and is recycled to the boiler. The liquor from the evaporator is sent to the fluidized bed where it comes in contact with air at elevated temperature. The water content is totally removed at this stage and the KOH is collected in powdery form and sent to the storage tank.
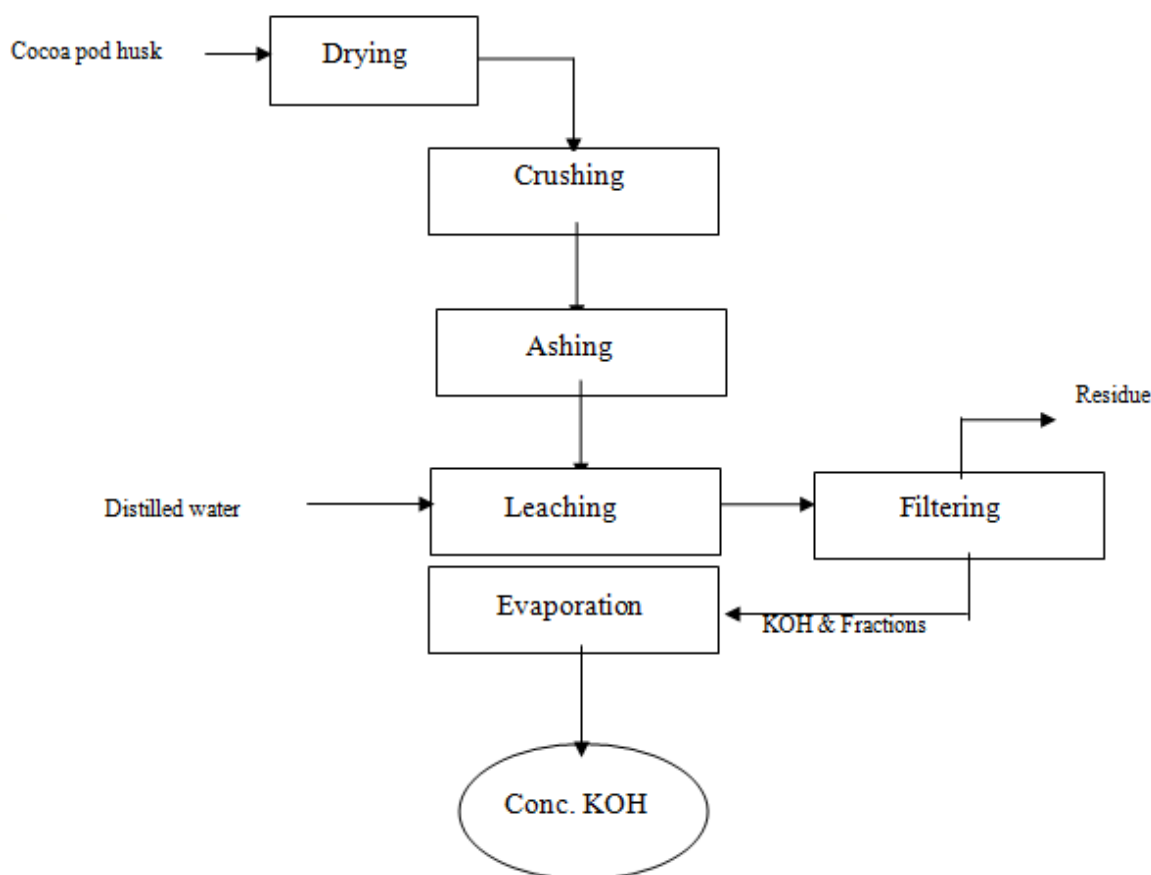
Figure 1: Production Flow Chart

2.3 Material and Energy Balance

The knowledge of material balance is a useful tool in determining the quantity of raw material required and the products produced. Material balance is also used to study the operation of plant, identification of sources of materials loss [22] etc. The simple material balance acquaints the process designer the maximum yield obtainable in this process while providing a quick check on the profitability of the proposed process. This is often accomplished by ensuring complete reaction and hundred percent recoveries. If the raw material cost is equal or greater than the product selling price, the process will not break even.

The general conservation equation for any process system is written as:

$$Input - output - depletion = accumulation - generation \quad (1)$$

For a process with no generation or depletion of material within the system, equation 3.1 becomes

$$Input - output = accumulation \quad (2)$$

In a steady state process, the accumulation term is zero, except in nuclear process. Mass is either neither generated nor consumed but if a chemical reaction occurs; particular chemical specie may be formed or consumed in the process. If there are no chemical reactions, the steady state balance reduces to

$$Input - Output = 0 \quad (3)$$

The mass balance is often expressed in terms of reaction, product and a material balance with respect to an entire system which is clearly identified by creating boundary round it.

Procedure

The calculation procedure involves:

i. Conversion of tonnes per day to kilogramme per day
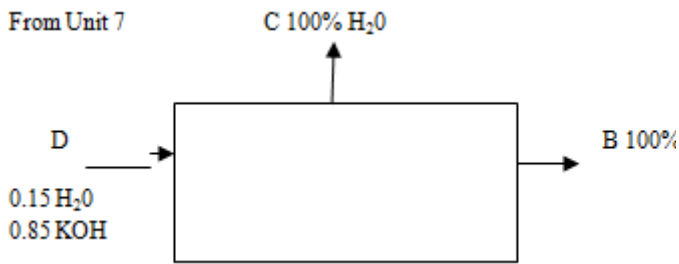ii. The material balance is based on a split fraction method

From unit 8

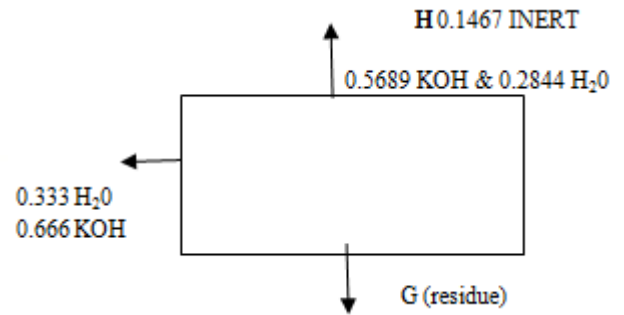The final product B=30,000 tonnes, 1 tonnes = 1,000 kg, therefore, 30,000,000 kg

Molecular weight of KOH= 56 kg/k mole

$$B \ in \ kmoles = \frac{30,000,000}{56}$$

$$B = 535714.28 \ kmoles$$

From Unit 7

$Input - Output = 0$

$$D - (B + C) = 0 \qquad (4)$$

The fluidized bed is capable of removing 15% of moisture

$$C = 15\% \, of D$$

$$C = 0.15D \qquad (5)$$

Substituting equation 5 into 4
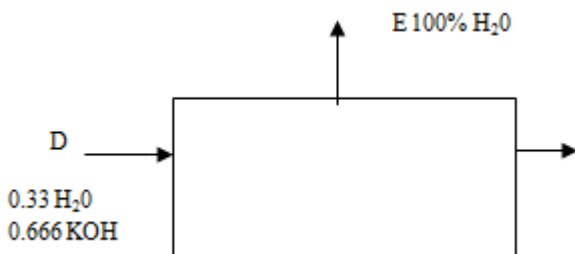
$$D - (B + 0.15D) = 0$$
$$0.85D = B$$
$$D = \frac{B}{0.85} = \frac{535714.286}{0.85}$$
$$D = 630252.101 kmoles$$

Unit 6

$Input - Output$

$$F - (D + E) = 0 \qquad (6)$$

$$water: 0.333F - 0.15D - E = 0$$
$$0.333F - E = (0.15 \times 630252.101) \qquad (7)$$
$$0.333F - E = 94537.815$$

$$KOH: 0.666F - 0.85D = 0$$
$$0.666F = 0.85D$$
$$D = 630252.101 kmoles$$
$$F = \frac{0.85(630252.101)}{0.666}$$
$$F = 804375.805 kmoles$$

Unit 5

$Input - Output = 0$
$$H - (F + G) = 0 \qquad (8)$$
$$H = F + G$$

Taking water balance
$$0.2844H = 0.333F + 0(G)$$
$$0.2844H = 0.333(804375.805)$$
$$H = 941832.430 kmoles$$

Substituting F and H into equation 8
$$H = F + G$$
$$G = H - F$$
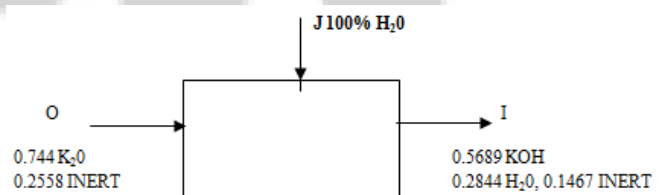$$G = 941832.430 - 804375.805$$
$$G = 137456.625 kmoles$$

Unit 4
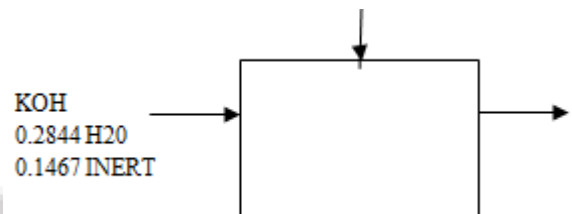
$Input - Output = 0$
$$I = H \qquad (9)$$
$$I = 941832.430 kmoles$$

Unit 3

$Input - Output + Generation - Consumption = 0$

$inert : 0.2558Q - 0.1467I + 0 - 0 = 0$

$substituting I = 941832.430$

$Q = 540136.112 kmoles$

Table 4: Composition and Molecular Weight of Mixture

Constituents	Composition	% Composition	Molar Mass	Molecular Weight
CaO	5.74	0.0574	56	3.2144
MgO	10.44	0.1044	40	4.176
K_2O	74.42	0.7442	94	69.9548
P_2O_5	7.83	0.0783	110	8.613
S_1O_2	1.57	0.0157	46	0.7222
Molecular weight of Mixture				86.6804

Molecular weight of mixture

$Q = \dfrac{86.6804}{1}$

$Q = 86.6804 kg / kmol$

$but Q = 540136.112 kmoles$

$Q = 540136.112(86.680)$

$Q = 46818998.19 kg$

Unit 2
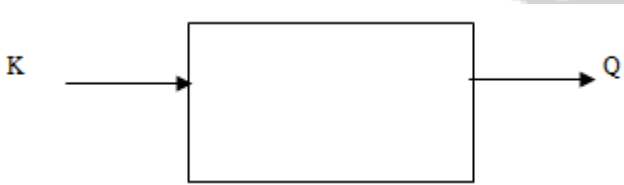
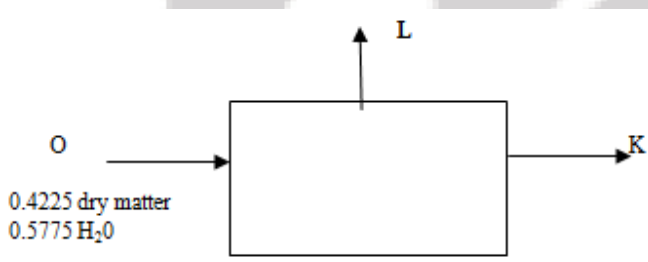$Input = Output + reac\tan t \ loss \ due \ to \ reaction$

$K = Q + reac\tan t \ loss \ due \ to \ reaction$

$K = 46818998.19 kg$

Unit 1

0.4225 dry matter
0.5775 H_2O

At steady state

$input = output$

$M = L + K$

$but L = 0.577M + K$

$M = 0.577M + K$

$0.4225M = K$

$K = 46818998.19 kg$

$M = 1,108,141,96.9 kg$

$M = 110,814.197 tonnes$ (10)

Another important pre-requisite for process and reactor design is energy balance. It is just as preliminary and essential as material balance. The energy requirement represents a major item of the cost of production and a proper economic evaluation cannot be carried out without performing both energy and material balance. Energy balance suggests possible energy recovery and potential saleable energy sources. Energy balance is calculated in accordance with the law of conservation of energy which is considered in terms of mechanical transfer due to pressure and volume variations and in terms of thermal heat. In calculating energy balance, boundaries or envelopes are used as I material balance to separate and distinguish the surrounding from the system into and out of which material and energy is being transferred. The energy content of stream is conveniently represented by the specification of the enthalpy of that stream. The specific enthalpy is a function of temperature and pressure while that of a mixture is also dependent on the composition. Wherever heat is transferred in the process to meet up the demand of the energy, steam was used to supply heat such as in reactor. Similarly, cooling water is used to remove excess heat where heat is evolved.

3. Assumptions

1. Changes in potential energy due to height differences, kinetic energy due to flow fluctuations, radiation due to temperature difference and surface energies are negligible and no work was performed on the process due to pressure and volume fluctuations
2. The heat lot through walls of process units or boundaries, piping etc. is negligible.
3. All enthalpies were calculated with reference to the datum temperature 0^0C (237K)
4. There is no pressure change, hence work of expansion and compression is small and since liquids and solids are almost incompressible, the effect of pressure on enthalpy is negligible.

Energy balance on drier

1. Datum temperature= 0^0C (237K)
2. Basis: 1 day operation
3. Input (enthalpy of inlet stream)

Cocoa pod husk

H_2O: $C_P = 0.9997$ Cal/g^{0}C

$KNH0_3$

$C_P = 0.292 Cal / g^0C$

$Q = MC_P \Delta t$

$= 3000 \times 10^3 \times 0.292 \times 60$

$= 5.26 \times 10^7 Cal / day$

$= 2.20 \times 10^8 J / day$

NH_4NO_3

$C_P = 0.416 Cal / g^0C$
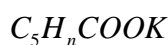
$Q = MC_p \Delta t$

$= 1000 \times 10^3 \times 0.416 \times 60$

$= 2.49 \times 10^7 Cal / day$

$= 1.04 \times 10^8 J / day$

C_5H_nCOOK

$C_p = 0.544 Cal / g^0C$

$Q = MC_p \Delta t$

$= 4500 \times 10^3 \times 0.544 \times 60$

$= 1.47 \times 10^8 Cal / day$

$= 6.16 \times 10^8 J / day$

Where:
m: mass of water in g/day;
C_P: specific heat of water in Cal/g^0C;

$\Delta t = temperature\ difference\ (^0C)$
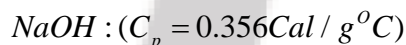
From equation 11

$Q = MC_p \Delta t$

$Q = 9624.61 \times 10^3 \times 0.9997 \times 25$

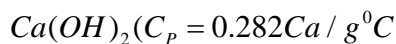$= 2.405 \times 10^8 Cal / day$

$= 1.007 \times 10^9 J / day$

$NaOH : (C_p = 0.356 Cal / g^OC)$

$Q = MC_p \Delta t$

$= 618.70 \times 10^3 \times 0.35 \times 25$

$= 5.50 \times 10^6 Cal / g^0C$

$= 2.30 \times 10^7 J / day$

$Ca(OH)_2 (C_P = 0.282 Ca / g^0C$
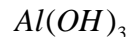
$Q = MC_p \Delta t$

$= 68.74 \times 10^3 \times 0.9282 \times 25$

$= 1.60 \times 10^6 Cal / day$

$= 6.67 \times 10^6 J / day$

$Al(OH)_3$

$C_p = mC_p \Delta t$

$= 137.49 \times 10^3 \times 0.47 \times 25$

$= 1.616 \times 10^6 Cal / day$

$= 6.750 \times 10^6 J / day$

Hence, total heat from the cocoa pod stream

$= (1.007 \times 10^9 + 2.30 \times 10^7 + 6.67 \times 10^6 + 6.75 \times 10^6) = 1.043 \times 10^9 J / day$

4. Water Stream

$C_p = 0.416 Cal / g^0C$

$Q = MC_P \Delta t$

$= 2337.66 \times 10^3 \times 0.416 \times 160$

$= 1.556 \times 10^9 Cal / day$

$= 6.515 \times 10^8 J / day$

Also,

$C_p = 0.457 Cal / g^oC$

$Q = mC_P \Delta t$

$= 3389.61 \times 10^3 \times 0.457 \times 160$

$= 2.478 \times 10^8 Cal / day$

$= 1.037 \times 10^9 J / day$

$P_2 0_5$

$Q = MC_p \Delta t$

$= 5522.73 \times 10^3 \times 0.42 \times 100$

$= 2.320 \times 10^8 Cal / day$

$= 9.695 \times 10^9 J / day$

Total heat from water stream equals

$= (6.515 + 10.37 + 96.95) \times 10^8 J / day$

$= 11.38 \times 10^9 J / day$

Total heat input to the reactor=heat from cocoa pod husk+ heat from water stream

$= (1.043 \times 10^9 + 11.38 \times 10^9)$

$= 1.242 \times 10^{10} J / day$

Output

$KNHO_3$

$C_P = 0.292 Cal/g {}^0C$

$Q = MC_P \Delta t$

$= 3000 \times 10^3 \times 0.292 \times 60$

$= 5.26 \times 10^7 Cal/day$

$= 2.20 \times 10^8 J/day$

NH_4NO_3

$C_P = 0.416 Cal/g {}^0C$

$Q = MC_p \Delta t$

$= 1000 \times 10^3 \times 0.416 \times 60$

$= 2.49 \times 10^7 Cal/day$

$= 1.04 \times 10^8 J/day$

C_5H_nCOOK

$C_p = 0.544 Cal/g {}^0C$

$Q = MC_p \Delta t$

$= 4500 \times 10^3 \times 0.544 \times 60$

$= 1.47 \times 10^8 Cal/day$

$= 6.14 \times 10^8 J/day$

$NaNO_3$

$C_P = 0.438 Cal/g {}^0C$

$Q = MC_p \Delta t$

$= 1314.74 \times 10^3 \times 0.48 \times 60$

$= 3.78 \times 10^7 Cal/day$

$= 1.58 \times 10^8 J/day$

H_2O

$C_P = 0.9997 Cal/g {}^0C$

$Q = MC_P \Delta t$

$= 11091.88 \times 10^3 \times 0.9997 \times 60$

$= 6.65 \times 10^8 Cal/day$

$= 2.78 \times 10^9 J/day$

The total heat in exit stream equals

$(2.20 + 1.04 + 6.14 + 1.58 + 27.8) \times 10^8$

$= 38.76 \times 10^8 J/day$

For a day operation, total heat in exit stream
$= 38.76 \times 10^8 J$

The heat required to raise the temperature from $25 {}^0C$ to $60 {}^0C$ in the reactor (i.e. cocoa pod husk).

$\Delta t = (60 - 25) = 35 {}^0C$

H_2O

$Q = MC_P \Delta t$

$= 9624.61 \times 10^3 \times 0.9997 \times 35$

$= 3.36 \times 10^8 Cal/day$

$= 1.40 \times 10^9 J/day$

KOH

$Q = MC_p \Delta t$

$= 3290.732 \times 10^3 \times 0.277 \times 35$

$= 3.20 \times 10^7 Cal/day$

$= 1.34 \times 10^8 J/day$

Stream 3

$Q = MC_p \Delta t$

$= 618.70 \times 10^3 \times 0.356 \times 35$

$= 7.71 \times 10^6 Cal/day$

$= 3.23 \times 10^7 J/day$

$Stream 4$

$Q = MC_p \Delta t$

$= 64.74 \times 10^3 \times 0.282 \times 35$

$= 6.38 \times 10^5 Cal/day$

$= 2.67 \times 10^6 J/day$

$Stream 5$

$Q = MC_p \Delta t$

$= 137.49 \times 10^3 \times 0.47 \times 35$

$= 2.26 \times 10^6 Cal/day$

$= 9.46 \times 10^6 J/day$

Total heat absorbed

$= (1.41 + 0.134 + 0.0323 + 0.00267 + 0.00946) \times 10^9$

$= 1.58 \times 10^9 J/day$

*Stream*6

$$Q = MC_p \Delta t$$

$$= 3389.61 \times 10^3 \times 0.45 \times 100$$

$$= 1.53 \times 10^8 Cal / day$$

$$= 6.37 \times 10^8 J / day$$

*Stream*7

$$Q = MC_p \Delta t$$

$$= 5522.73 \times 10^3 \times 0.427 \times 100$$

$$= 2.32 \times 10^8 Cal / day$$

$$= 9.71 \times 10^8 J / day$$

The heat dissipated in the reactor

$$= (0.407 + 0.637 + 0.986) \times 10^9$$

$$= 2.03 \times 10^9 J / day$$

$$\Delta H_{reaction} = \sum \Delta H_{f(product)} - \sum \Delta H_{f(reactant)}$$

reaction(*i*)

$$\Delta H_{reaction} = [(-68.20 - 109.79) - (-41.35 - 114.96)]29.7 KCal / day$$

$$= -643.896 KCal / day$$

reaction(*ii*)

$$\Delta H_{reaction} = [(-108.66 - 68.32) - (-112.19 - 41.25)]15.47 KCal / day$$

$$= -364.88 KCal / day$$

reaction(*iii*)

$$\Delta H_{reaction} = [(-228.29 - 2 \times 68.32) - (-239.2 - 41.35)]0.93 KCal / day$$

$$= -78.50 KCal / day$$

reaction(*iv*)

$$\Delta H_{reaction} = [(-680.89 - 3(68.32)) - (-304.8 - 3 \times 41.32)]$$

$$= -885.85 + 428.76$$

$$= 457.09 KCal / day$$

$$= 457.09 KCal / mol \times 2.49 mol / day$$

$$= -1138.15 KCal / day$$

reaction(*v*)

$$\Delta H_{reaction} = [(-2714 - 68.32) - (583.8 - 114.96)]$$

$$= -2782.32 + 698.76$$

$$= -2083.56 KCal / mol$$

$$= -2083.56 KCal / mol \times 29.22 mol / day$$

$$= -60881.62 KCal / day$$

Total heat of reaction

$$= (-643.896 - 364.88 - 78.50 - 1138.15 - 60881.62) KCal / day$$

$$= 6.31 \times 10^7 Cal / day$$

$$= 2.64 \times 10^8 J / day$$

Net heat of reaction = Heat input - Heat output + Heat added – Heat of reaction

$$= [1.242 \times 10^{10} - 3.876 \times 10^9 + 1.58 \times 10^9 - 2.64 \times 10^8]$$

$$= 9.86 \times 10^9 J / day$$

Net heat balance in the reactor is the amount of heat removed per day operation to maintain an isothermal condition in the reactor at $60^0 C$. The heat evolved will be removed by cooling.

$$Q = MC_p \Delta t$$

$$MC_p (t_2 - t_1)$$

t_1= inlet temperature of cooling water= $25^0 C$
t_2= outlet temperature of cooling water= $47^0 C$
C_p for water =4.184 KJ/KgK

$$7.30 \times 10^8 = M \times 4.184 \times [47 - 25]$$

$$M = 7.93 \times 10^6 g / day$$

$$M = 7.93 \times 10^3 kg / day$$

Heat transferred by water at $250.3^0 C$ to $100^0 C$ equals

$$(1087.4 - 422) KJ / Kg$$

$$= 665.4 KJ / kg$$

Total heat transferred by stream from $250.3^0 C$ to $100^0 C$ water equals 1712.9 KJ/kg

Total heat transferred by water at $250.3^0 C$ to $100^0 C$ equals

$$(665.4 + 1712.9) KJ / Kg$$

$$= 2378.3 KJ / Kg$$

$$= 2.378 \times 10^6 J / Kg$$

Heat to be supplied to maintain isothermal condition in the hydrolysis $= 7.9 \times 10^9 J$
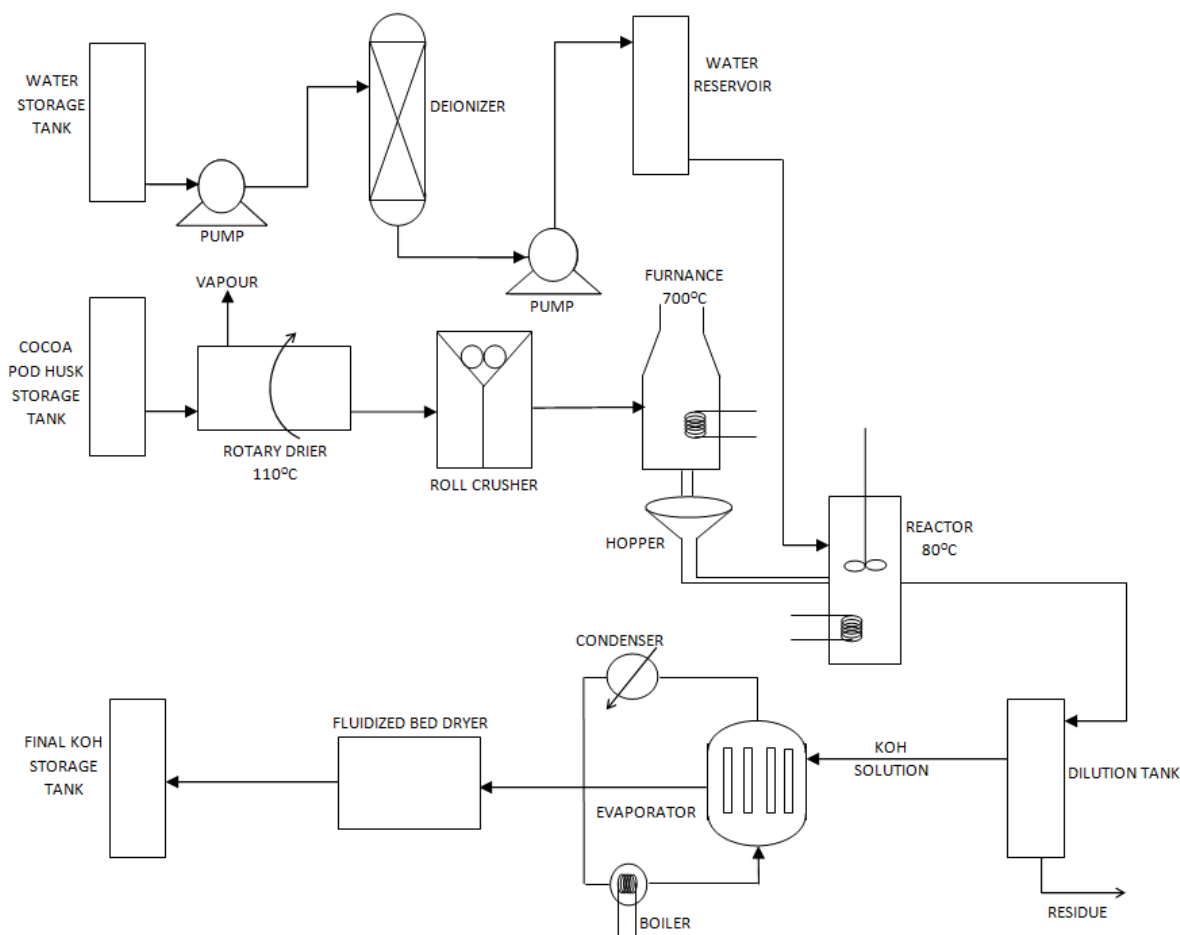
Let M = Mass of stream

Figure 2: Schematic of Process Flow Diagram

2.4 Process Control and Instrumentation

In the design of an industrial plant, design variables are a function of methods used for plant operation and control. Processes must be controlled precisely to give more uniform and higher quality caustic potash by the application of control often leading to higher profit. Therefore, the flow pressure, liquid level, temperature, composition or any other inventory, environmental or quality variable must be held at a desired value with the aid of some control measure or instrument applied to it. Such instrument includes:

1. Temperature sensors: for heaters, dryers
2. Gauges: Employed to measure the liquid level in the vessel or storage tank or the temperature and pressure in the piping system level. Temperature and pressure gauges are mounted to enable plant operation obtain a visual reading.
3. Control: Employed to maintain a specified liquid level, temperature and pressure flow in and out of the vessel.
4. Alarm: Signals via light or horn employed to indicate when liquid level, temperature or pressure level is too high or low. It is also a good indicator for conditions of no flow or reverse flow
5. Indicator: to indicate liquid level temperature, pressure or flow rate inside the piping system.

6. Recorders: To record the liquid level, temperature, pressure and flow rate in the piping system.
7. Cascade Control: to eliminate the effects of some disturbances and to improve the dynamic performance of the control loop.

Process control systems serves to keep the process within known safe operating limits so as to achieve the designed production rate, maintain the caustic potash within the desired specification and to operate at an optimum production cost. The operation modes of the process control system include:

1. Automatic monitoring of the process of potassium hydroxide production to detect an abnormal condition or an undesirable event through a sensor or a process unit. This operation mode is applicable through provision of instrument switches (pressure level etc). Its activation will generate signal alarm
2. Automatic shut down of the process of KOH production on detection of abnormal condition or an undesirable event.

5. Conclusion and Recommendation

Nigeria has comparative advantage in the production of caustic potash from agricultural waste. With the availability of diverse caustic potash feedstock if

harnessed prudently, Nigeria can compete favorably with the rest of the world in the production of caustic potash from agricultural wastes. Besides, the use of agricultural waste for caustic potash production helps solve disposal problems of agricultural waste. Instead of indiscriminate dumping; it would be exploited for caustic potash production thus, converting waste to wealth. In addition, plant design and integration of caustic potash production processes seeks an economic, safe and improved method of caustic potash production from locally sourced materials thereby, building indigenous capabilities with attendant reduction of unemployment hence, a major boost for the Nigerian economy. More researches should be carried out in this area and agricultural waste should be prudently harnessed to reduce dependence on synthetic chemicals. Besides, the design data in this work will be useful in the integration of all processes involved in the production of caustic potash from agricultural wastes.

References

[1] Lerner, B. R. (2000). Wood Ash in the Garden. Purdue University Consumer Horticulture, Available at http://www.hort.purdue.Edu/ext/woodash.html.

[2] Onifade, K. R. (1994). The Potential Application of Cocoa Pod Husks for the Manufacture of Caustic Potash. Journal of Agricultural Technology 2(2):59-64.

[3] Ashford, R. D. (1994). Ashford's Industrial Chemicals. London Waxlelength Publishers Ltd pp. 1-45.

[4] Edewor, J. O. (1994). Chemicals Production from Local Fossil Fuels and the Nigerian Balance of Trade. 3: 5-9.

[5] Adewuyi, G. O., N. O. Obi-Egbedi and J. O. Babayemi (2008). Evaluation of Ten Different African Wood Species for Potash Production. Int. Journal of Physical Sciences 3:63-68.

[6] Babayemi, J. O. and Adewuyi, G. O. (2010). Assessment of Combustion and Potash Production as Options for Management of Wood Waste. Journal of Applied Sciences and Environmental Management. 14(1) 73-75.

[7] Taiwo, A. A., I. Oluwadare, A. O. Shobo and A. S. Amolegbe (2008). Extraction and Potential Application of Caustic Potash from Kolanut Husk and Plantain Peels. Journals of Scientific Research and Essay. 3(10) 515-517.

[8] Babayemi, J.O., K. T. Dauda, D. O. Nwude and A. A. Kayode (2010a). Evaluation of the Composition and Chemistry of Ash and Potash from Various Plant Materials. A Review: Journal of Applied Sciences 10: 1820-1824.

[9] Onyegbado C. O., Iyagba, E. T. and Ofor, O. J. (2004). Solid Soap Production Using Plantain Peel Ash as Source of Alkali. Journal of Applied Sciences and Environmental Management. 6(1) 73-77.

[10] Ankrah, E. A. (1974). Chemical Studies of Some Plant Waste from Ghana. Journal of Sciences of Food and Agriculture. 25(10) 1229-1932.

[11] Babayemi, J.O., G. O. Adewuyi, K. T. Dauda and A. A. Kayode (2010). The Ancient Alkali Production Technology and the Modern Improvement. A Review: Asian Journal of Applied Sciences. 4:22-29

[12] Afrane, G. (1992). Leaching of Caustic Potash from Cocoa Husk Ash. Bioresource Technology. 41(2) 101-104.

[13] Bhattacharyya, D. K. and B. Chatterjee (1984). Palm Oil Fatty Acids in Soaps and Detergent Formulation. Journal of American Chemical Society. 61:417-419.

[14] Akunna, T. O., E. O. Ahaotu, C. N. Osuji and C. C. Ibeh (2013). Production of Soap Using Palm Bunch Ash. International Journal of Applied Sciences and Engineering. 1(2) 79-82.

[15] Taiwo, O. E. and F. A. O. Osinowo (2001). Evaluation of Various Agro-waste from Traditional Soap Production. Bioresource Technology 79: 95-97.

[16] Ogundiran, M. B., J. O. Babayemi and C. G. Nzeribe (2011). Cashew nut Shell as Source of Ash for Potash Production. Bioresource Tecnology 6(1) 529-536.

[17] Babayemi, J. O. and Dauda (2009). Evaluation of Solid Waste Generation Categories and Disposal Options in Developing Countries. A Case of Nigeria. Journal of Applied and Environmental Management. 13:83-88.

[18] Kevin, M. D. (2003). Projects from the Creation of Fire to the Production of Plastic. Universal Publisher, Australia. pp. 1-20.

[19] Irvine, F. R. (1965). West African Crops. Oxford University Press. 3rd Edition. pp. 97-114.

[20] Curlin, L. C., T. V. Bommaiju and C. B. Hansson (1991). Alkali and Chlorine Products and Hazardous Materials. New York: Marcel Dekker. Kirk-Other Encyclopedia of Chemical Technology 1: 938-1025.

[21] Cheremisinoff, N. P. (1999). Hand book of Industrial Technology. pp.12-30.

[22] Coulson, J. M. and J. F. Richardson (1999). Chemical Engineering Design. Vol. 6 3rd Edition. Butterwoth Heinemann Publisher, London. pp. 257-300