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Mass Balance and Quality Assessment of Potash from Cocoa Husk Ash from Ghana

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Abstract: ***The study assesses the mass balance and quality of potash produced from cocoa husk ash from Ghana. Potassium salt was produced by combusting dry cocoa husk to ash and mixing the ash with deionized water, filtering and evaporating the filtrate to dryness. The quantity of potassium carbonate present in the potassium salt was 98.4 % on dry basis. Multielement analysis using ICP/OES indicates elevated elements concentration for boron (140 mg/kg), calcium (170 mg/kg), sodium (140 mg/kg), silicon (180 mg/kg), strontium (2.2 mg/kg), molybdenum (4 mg/kg) and phosphorus (2400 mg/kg) but Ag, Al, As, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Li, Mg, Mn, Ni, Pb, Sb were below detection limit. The material balance based on previous work suggests the following ratio: 124 (fresh cocoa husk): 25 (dry cocoa husk): 2 (Ash): 1 (potassium salt) which serve as a quick estimate for any prospective cocoa husk potash industry. The quality of the potassium salt provides an unusually very high amount of potassium (560, 000 mg/kg) present in the potassium salt, making the ash very useful feedstock for the potash industry.***

Keywords: Ash, Potash, Potassium Carbonate, Cocoa Husk

1.Introduction

In Ghana, most cocoa farmers dispose the cocoa husk by simply segregating it from the trees and left to decay. Some have made small chemical businesses in which the husks are burned for ash for potash extraction which is used in local soap industry. This work seeks to give a quick estimate of the various processing stages of the potash industry by way of carrying out a material balance based on data from previous works in the literature and also to access the quality of potassium carbonate in potash salt produced under laboratory condition.

2.Literature Review

Theobroma cocoa L. (Sterculiaceae) is a high economic crop in several tropical countries. The average weight of a normal size cocoa pod is about 500 g [1, 2] and its beans constitute about 10% of the cocoa pod's fresh weight [3]. Thus only about 10% by weight of the cocoa pod is commercialized (beans) whilst 90% by weight, mainly pulp and husk is discarded as cocoa waste [4]. The fresh cocoa husk is approximately 52-76 % of the weight of the fresh cocoa pod [5]. Therefore, for each ton of dried cocoa beans produced, about ten tons of fresh cocoa husk are generated [6] as waste biomass. The moisture content of the fresh cocoa husk has been reported to be between 81-90% of the weight of the fresh cocoa husk [7, 8]. Additionally, the husk is not suitable for direct use as a soil amendment material as it is reported to be a major source that promotes the fungal black pod disease, which reduces crop yield of up to about 30% [6, 9, 10] for which reason efforts are made to effectively utilize it.

Several plant ashes contain appreciable amounts of potassium from which potassium carbonate may be extracted. The amounts of potassium carbonate in some of these ashes have been reported by many researchers. Some reported amounts are-ripe plantain peel (78%), fresh plantain trunk (94%), unripe plantain peel (82%), palm bunch (43.2 %), groundnut shell (16.7%), sorghum chaff (12.40%), and cocoa husk ranging from 40 to 77% [7, 11, 12, 13, 14]. The most abundant feedstock for potash production in Ghana may be the cocoa husk (Afrane, 1992). The Cocoa Research Institute of Ghana has come out with a manual for extracting cocoa potash and producing soft cocoa soap in its Technical Bulletin No.24 [15]. Work carried out by [7] showed that the ash produced from the cocoa husk has unusually high potassium content (43.6%), which is estimated to have the potential to earn Ghana over 50, 000 tonnes per annum of potassium carbonate with a market value of some tens of million dollars. Cocoa husk can be put to many other uses. It is a good source of pectin (pectin extracted from several plant by-products are widely used as gelling, thickening, and stabilizing agents) as reported by [16]. The protein content in the cocoa husk makes it useful for feeding farm animals [17]. It is also used as a source of energy [18, 19, 20, 21]. The focus of this paper is to quantify the amount of potassium carbonate in tons of potassium salt (especially, for the potash industry); by carrying out a material balance based on the data provided by [22, 23] and also to assess the quality of the potassium carbonate produced from the cocoa pod husk ash under laboratory conditions.

3.Materials and Method

3.1 Materials

Aluzinc metal steel (8 ft *4 ft), deionized water, cocoa husk, lighter, Buchner funnel filtration setup, deionized water (18.2 Mohm/cm), Agilent 7900 Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), laboratory balance, laboratory oven, filter paper (Whatman No.41), digestion block, pipette, burette, Erlenmeyer flask, volumetric flask, concentrated nitric acid solution (analytical grade), concentrated hydrochloric acid solution (analytical grade) and methyl orange indicator.

3.2 Method

Details of cocoa potash extraction process obtained from [15, 22, 23] showed that 5.4 kg of potassium salt were produced from 670 kg of fresh cocoa husk. His proposed schematic has been modified as shown in Figure 1 below:

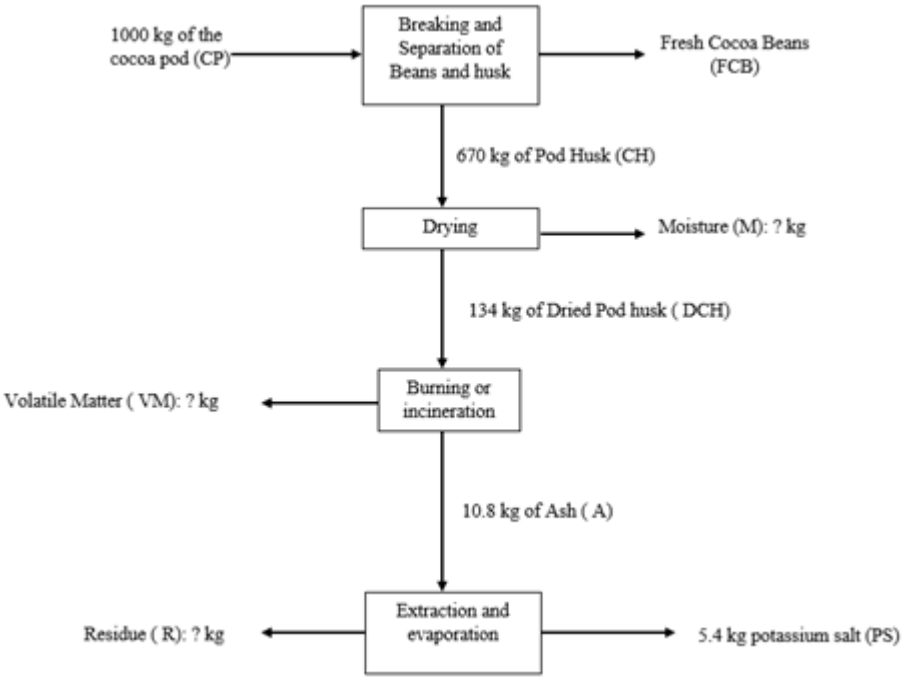

Figure1: Schematic of the potash production process

3.1.1 Material Balance on the Schematic of the Potash Production Process

Breaking and Separation of Beans and Husk

CP = FCB + CH ……1
FCB = CP – CH = (1000 – 670) kg = 330 kg
Percentage FCB = (330 kg/1000 kg) * 100 = 33%, percentage CP = (100 – 33) % = 67%

Drying

CH= M + DCH …… 2
M = (670 – 134) kg = 536 kg
Percentage M = (536kg/670 kg) * 100 = 80 %, Percentage DCH = (100 – 80) % = 20 %

Burning or Incineration

DCH = VM + A …… 3
VM = (134 – 10.8) kg = 123.2 kg
Percentage VM = (123.2 kg/134 kg) * 100 = 91.94 %, Percentage A = (100 – 91.94) % = 8.06%

Extraction and Evaporation

A = R + PS …….4
R = (10.8 – 5.4) kg = 5.4 kg
Percentage R = (5.4kg/10.8 kg) * 100 = 50 %, Percentage PS = (100 – 50) % = 50 %

3.1.2 Preparation of Potassium Salt from the Cocoa Husk

The dried cocoa husk was incinerated/combusted at ambient conditions on the metal sheet. The ash produced was mixed with deionized water and the resulting mixture filtered using the Buchner Filtration Setup. The filtrate obtained was placed in a stainless-steel pan and evaporated to dryness by placing the pan on a gas burner to obtain potassium salt.

3.1.3 Quality Assessment of Potassium Salt

One (1) g of dried potassium salt was weighed into the 50 ml digestion tube. Then, 2.5 ml of the concentrated nitric acid solution were pipetted and added to the potassium salt in the digestion tube. The mixture was swirled, and 2.5 ml of concentrated hydrochloric acid solution was pipetted and added to the contents of the digestion tube. The digestion tube and contents were placed on a pre-heated hot block at 110 ^{o}C for 40 minutes. Thereafter, 10 ml of deionized water was added to the contents in the digestion tube; and the heating process repeated at the

same temperature for one hour twenty minutes. The contents in the digestion tube were allowed to cool following dilution with deionized water to the 50 ml mark. The resulting mixture was filtered using filter paper. The concentrations of elements in the filtrate were read against appropriate blank and standard solutions using the ICP-OES; following the method used by [24].

3.1.4 Quantification of Potassium Carbonate in the Potassium Salt

The quantity of potassium carbonate in the potassium salt was determined by Titrimetric Method as proposed by [25]

4.Results and discussion

As shown in Table 1, the mass balance shows that a ton (1000 kg) of fresh cocoa pods gave 670 kg of fresh cocoa husk (about 67% of the starting material). This percentage fits well with the percentage range reported by [5]; who said the percentage weight of the fresh cocoa husk varied between 52 – 76% of the weight of the fresh cocoa pods. The percentage moisture content (80%) in the fresh cocoa husk obtained in the material balance in this work also agreed with the work carried out by [7, 8]. The results clearly showed that the combustible fraction of the cocoa husk was about 92%; supporting the report made by other researchers [18, 19, 20, 21, 26] that dry cocoa husk was a very good source of energy. The percentage of potassium salt from the mass balance is 50 % of the initial ash input. It is, however, unfortunate that the quantity of residue (5.4 kg) left behind after production of the potassium salt was quite substantial. Therefore, one needs to make provision for the disposal of the residue anticipated to be produced and or use this residue for a valuable product. Our personal experience has shown that improper disposal of this waste can lead to an imbalance in the amount of nutrients in the soil found in the disposal area affecting plant growth.

Table 1: Material Balance on Potash Production Process

SN	Process	Input (kg)	%	Output 1 (kg)	%	Output 2 (kg)	%
1	Breaking and separation of beans and husk	CP: 1000	100	FCB: 330	33.00	CH: 670	67.00
2	Drying	CH: 670	100	M: 536	80.00	DCH: 134	20.00
3	Burning or Incineration	DCH: 134	100	VM: 123.2	91.94	A: 10.8	8.06
4	Extraction and Evaporation	A: 10.8	100	R: 5.4	50.00	PS: 5.4	50.00

The potassium salt also contained minerals such as boron (140 mg/kg), calcium (170 mg/kg), sodium (140 mg/kg), silicon (180 mg/kg), strontium (2.2 mg/kg), molybdenum (4 mg/kg), phosphorus (2400 mg/kg) and potassium (560, 000 mg/kg) as shown in Table 2, indicating that the cocoa husk was highly mineralized with the major element being potassium as reported by [7].

Table 2: Elemental Levels in the Potassium Salt

Element	Chemical Symbol	Result (mg/kg)	Reporting Limit
Silver	Ag	<1.0	1.0
Aluminum	Al	<1.0	1.0
Arsenic	As	<2.0	2.0
Boron	B	140.0	3.0
Barium	Ba	<0.3	0.3
Beryllium	Be	<0.3	0.3
Bismuth	Bi	<3.0	3.0
Calcium	Ca	170.0	5.0
Cadmium	Cd	<0.3	0.3
Cobalt	Co	<0.3	0.3
Chromium	Cr	<0.3	0.3
Copper	Cu	<0.5	0.5
Iron	Fe	<1.0	1.0
Potassium	K	560000.0	10.0
Lithium	Li	<0.3	0.3
Magnesium	Mg	<5.0	5.0
Manganese	Mn	<0.3	0.3
Molybdenum	Mo	4.0	1.0
Sodium	Na	140.0	5.0
Nickel	Ni	<0.5	0.5
Lead	Pb	<1.0	1.0
Antimony	Sb	<3.0	3.0
Silicon	Si	180.0	2.0
Tin	Sn	<3.0	3.0
Strontium	Sr	2.2	0.3
Titanium	Ti	<0.3	0.3
Vanadium	V	<0.5	0.5
Zinc	Zn	<0.5	0.5
Phosphorus	P	2400.0	5.0

The purity of potassium carbonate in the potassium salt gave 98.4% on dry basis as shown in Table 3. This result presupposes that with good filtration and using dimineralised water high purity of the potassium carbonate can be achieved

Table 3: Percentage Potassium Carbonate in Potassium Salt

Compound	Chemical formula	Unit	Result	Reporting level
Potassium Carbonate	K_2CO_3	%	98.4	100

5.Conclusion

The material balance carried out based on earlier works by [22, 23] suggest the following ratio: 124 (fresh cocoa husk): 25 (dry cocoa husk): 2 (Ash): 1 (potassium salt) as a quick estimate for any prospective cocoa husk potash industry. This work concludes that cocoa husk is a very good starting material from which potassium salt can be produced for the potash industry. The quantity of potassium carbonate in the potassium salt was estimated to be about 98.4% on dry basis under laboratory conditions. Thus, indicating the quality of the potassium salt as far as the quantity of the potassium carbonate is concerned. The unusually very high amount of potassium (560, 000 mg/kg) present in the potassium salt makes the ash (from which the potassium salt was obtained) very useful feedstock for the potash industry.

6.Future scope

We envisage sampling the potassium salt produced by cocoa farmers sold on the market to access its quality in terms of potassium carbonate and other elemental composition. This would give potential buyers an idea of the quality to expect on the market for proper planning.

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