Processing of East African Highland Green Bananas: Banana Waste Characterization for Bio-Energy Production in Uganda

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"Future Agriculture: Socio-ecological transitions and bio-cultural shifts"
Tropentag, September 20-22, 2017, Bonn, Germany.

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INTRODUCTION

Uganda is the second largest global producer of bananas after India and the leading in Africa, with annual production estimated at 9.77 million tonnes [2,4]. The East African highland cooking banana subgroup (AAA-EA group) locally called *matooke*, is the major grown variety and a leading staple food [5].

However, both production systems and banana fruit processing accumulate large quantities of waste residues comprising rotten/damaged fruits, peels, fruit-bunch-stem (stalks), leaves, fibers, pseudo-stem, and rhizome. Banana fruit processing alone has been estimated that more than three million tonnes of banana waste are generated annually in the country [5].

Besides, Uganda's banana industrialization relies mainly on costly imported petroleum products for fuel energy and is grappling with inadequate and expensive energy [3]. Hence, utilization of banana waste as feedstock for energy production to relieve the banana industry from both energy scarcity and reliability can be the best option and first priority for managing banana waste in Uganda. Among the applicable waste-to-energy technologies, anaerobic digestion to generate biogas has been recommended as the most appropriate for biomass with high moisture content such as banana waste [3].

OBJECTIVES

The objective of this research study was to assess the key steps in processing of green bananas into pulp, and auditing and characterization of the major resulting residual wastes namely peels, peduncle (fruit-bunch stalk) and fruit discard, in order to evaluate their potential as feedstocks for biogas production.

METHODOLOGY

The study was undertaken following a reconnaissance visit to western Uganda (figure 1), the highest banana producing region in Uganda [6].

The study was conducted for a year and data was collected through guided survey along the processing plant, open-ended interviews, photography and sampling for laboratory analysis .

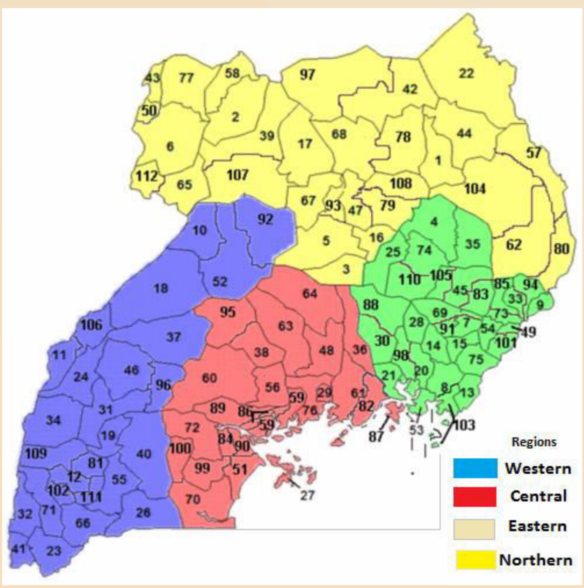

Fig.1: Banana productivity per region in Uganda: Western 68%; Central 23%; Eastern 8% and Northern< 1% [6].

Banana waste samples for laboratory analysis were collected from different processing streams and transported to the laboratory for analysis and biogas production experimentation at the Department of Biochemistry, Makerere University, Kampala-Uganda.

Sampling was done four times at an interval of three months for one year; between January and December 2015.

At the laboratory, raw banana waste samples were shredded into a homogeneous paste (figure.2) using an organic shredder (TR 200: Organic Shredder, BrazAfric Enterprises LTD).

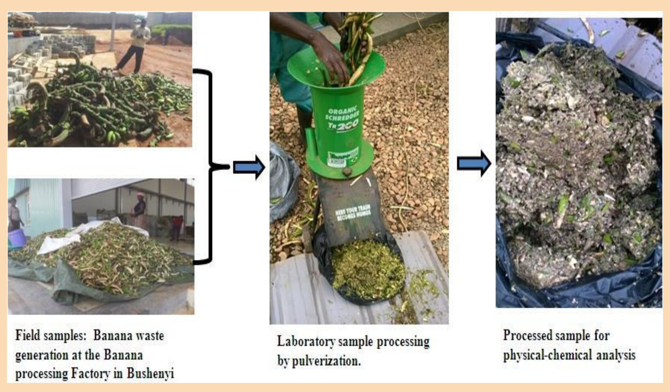

Fig.2: Sample preparation for physico-chemical analysis

Laboratory analysis was done in triplicates for physico-chemical parameters following standard methods described by [1,7]. Parameters analyzed were: moisture content, total solids, volatile solids, ash content, organic carbon, organic matter, total Kjeldahl nitrogen, proteins, starch, sugars, crude fat, cellulose, hemicelluloses and lignin content.

RESULTS

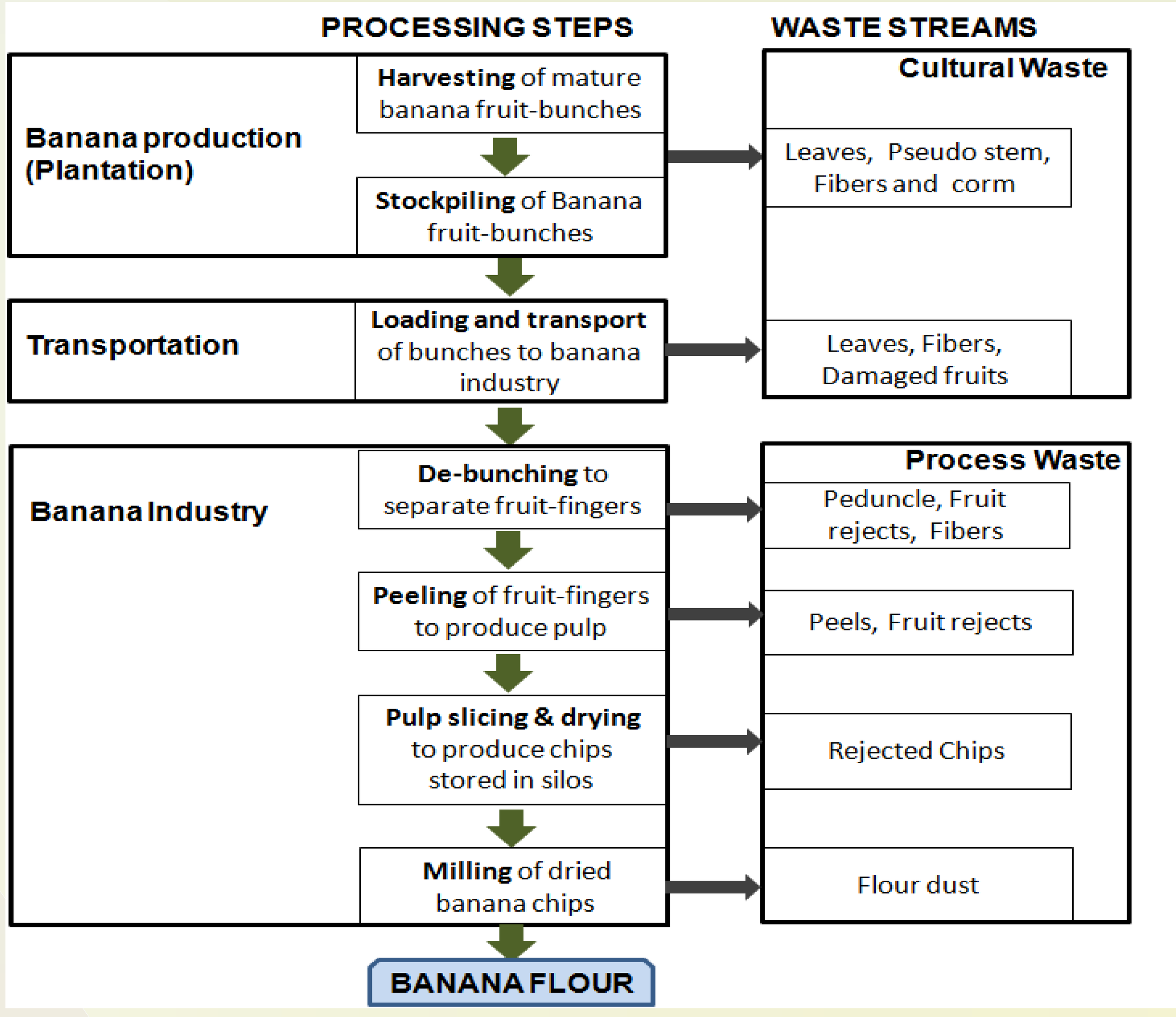

Fig. 3. Steps in banana fruit processing and major waste streams

Fig. 4. Major waste fractions generated from banana processing industry

Table 1. Current methods for management of banana waste

Waste stream	Current Management	Major Challenge
Process wastes		
Peels	▪ Animal feed supplement	▪ Only small fraction used ▪ Spread of plant disease such as Banana Bacterial Wilt
	▪ Dumping	▪ Emission of GHGs ▪ Water-body eutrophication by leachate ▪ Spread of plant Disease such as Banana Bacterial Wilt
Peduncle	▪ Dumping	▪ Water-body eutrophication by leachate ▪ Emission of GHGs ▪ Spread of plant Disease such as Banana Bacterial Wilt
	▪ Mulching	▪ Spread of plant Disease such as Banana Bacterial Wilt
	▪ Direct use of dried materials for Fuel	▪ Air-pollution by smoke emissions
Fruit rejects	▪ Animal feed supplement	▪ Spread of plant Disease such as Banana Bacterial Wilt
Cultural (Production)Wastes		
Leaves, Pseudo-stem, Fibre and Corm	▪ Mulching	▪ Spread of plant Disease such as Banana Bacterial Wilt
	▪ Dumping	▪ Water-body eutrophication by leachate ▪ Emission of GHGs ▪ Spread of plant Disease such as Banana Bacterial Wilt
	▪ Direct use of dried materials for Fuel	▪ Air-pollution by smoke emissions

Table: 2. Residual fractions from processing of green bananas

Residues per unit fruit bunch	% wet weight
Pulp	40.1 ± 3.5
Peels	50.2 ± 3.4
Peduncle	7.1 ± 1.7
Reject Fruits	2.6 ± 1.4
Total waste	59.9 ± 1.5
Total Waste: Pulp Ratio	1.5 ± 0.4
Peel: Pulp Ratio	1.3 ± 0.2
Peduncle: Pulp ratio	0.2 ± 0.1

RESULTS

Table 3: Physico-chemical composition of green banana waste

Parameters	Process streams				
	Peels	Peduncle	Fruit reject	Mixed waste	Pulp
MC ^{wb}	83.30 ± 3.04	90.50 ± 2.70	78.61 ± 2.21	85.47 ± 0.35	70.31 ± 4.62
TS ^{wb}	16.71 ± 2.33	9.51 ± 3.10	21.40 ± 2.02	14.55 ± 0.35	29.68 ± 3.11
VS ^{db}	86.78 ± 2.33	80.91 ± 3.02	88.71 ± 2.11	91.79 ± 0.16	96.11 ± 1.12
Ash ^{db}	13.22 ± 2.00	19.11 ± 3.53	11.32 ± 1.91	8.21 ± 0.16	3.90 ± 0.40
OC ^{db}	41.03 ± 4.31	40.02 ± 0.81	53.09 ± 4.71	51.99 ± 0.26	56.13 ± 2.10
OM ^{db}	89.04 ± 1.44	81.12 ± 1.01	87.11 ± 4.32	87.00 ± 0.50	89.83 ±3.33
TKN ^{db}	1.20 ± 0.09	1.93 ± 0.21	0.89 ± 0.32	1.26 ± 0.50	0.74 ± 0.11
C:N ratio	34.19 ± 1.31	20.74 ± 2.11	59.65 ± 1.38	41.26 ± 0.02	75.68 ± 1.10
Protein ^{db}	7.53 ± 1.21	12.06 ± 2.00	5.56 ± 1.81	7.88 ± 0.01	4.63 ± 0.62
Starch ^{db}	40.11 ± 2.22	1.73 ± 0.97	51.21 ± 2.13	50.30 ± 2.01	80.70 ± 2.30
Sugars ^{db}	1.42 ± 0.11	0.01 ± 0.01	3.61 ± 0.51	0.29 ± 0.03	4.11 ± 2.11
Cellulose ^{db}	13.09 ± 0.09	31.21 ± 1.50	4. 11 ± 0.13	21.16 ± 2.00	Nil
Hemicellulose ^{db}	14.66 ± 0.31	8.83 ± 0.13	4.88 ± 0.46	10.46 ± 0.51	1.21 ± 0.01
Lignin ^{db}	13.97 ± 0.02	18.77 ± 1.9	4.20 ± 0.20	11.31 ± 1.33	Nil
Crude Fat ^{db}	1.52 ± 0.22	0.33 ± 0.10	1.16 ± 0.19	1.43 ± 0.11	0.71 ± 0.16

MC = Moisture Content; TS = Total Solids; VS= Volatile solids; OC= Organic Carbon; OM= Organic Matter; TKN= Total Kjeldahl Nitrogen; *wb* = wet basis (% wet weight); *db* = dry basis (% TS)

DISCCUSSION

Results from the survey indicated that large quantities of banana waste were generated both at farm production level and during the processing of fruit-bunch into pulp. Waste fractions at production level were mainly cultural comprising the leaves, fibres, pseudostems and corm (**Figure.3**). The waste fractions from banana fruit processing were mainly peels, peduncle and damaged fruits (**Figure.4**). The huge quantities of waste generated was majorly attributed to the short shelf life of mature bananas. The major forms of banana waste disposal were by dumping and being left in plantations as mulches (**Table 1**). Besides, a challenge of lack of a 24hour supply of cheap and reliable sufficient energy for complete drying of banana pulp into dried products with consistent standard quality was prominently noted for both industry and local farmers. Quantitative analysis based on percent weight by residual fraction revealed that processing of a unit bunch of green bananas generates 40% as pulp and 60% as total waste residues (**Table 2**) with total waste to pulp ratio of 1.5:1 and peel to pulp ratio of 1.3:1. The high waste to pulp ratio was attributed to high moisture content of over 80%. Qualitatively, banana waste had higher carbon content than total nitrogen that translated into a high C:N ratio of 41:1. The waste was also lignocellulosic comprising; cellulose 21.16 %, hemicelluloses 10.46 % and lignin 11.31 % (**Table 3**).

CONCLUSION

The huge banana wastes generated and currently underutilized are rich in organic matter with high moisture content and thus a good substrate for biogas production through anaerobic digestion. Appropriate pre-treatment of its lignocellulose content would be required to enhance its digestibility and improve biogas yield.

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ACKNOWLEDGEMENT

This research was supported by the RELOAD project.

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