Improving sustainability and circularity of palm oil by anaerobic digestion of empty fruit bunch, mesocarp fibre, and palm oil mill effluent, enabling self-sufficient energy production from biogas

J.A. Voogt[1], J.C. Barrera Hernandez[2], J.W. van Groenestijn[1], H.W. Elbersen[1], J.A. Garcia-Nunez[2]
[1]Wageningen Food & Biobased Research
[2]Colombian Oil Palm Research Centre, Cenipalma, Bogotá, Colombia

EUBCE
29th European Biomass Conference & Exhibition

Introduction

Colombia is the largest palm oil producer outside of Asia. To expand the sales market, it is important to improve the sustainability and circularity of palm oil production. A palm oil mill processes fresh fruit bunch (FFB) into crude palm oil (CPO) and palm kernel oil. Per tonne of CPO an equal amount (in dry weight) of residue is generated, including empty fruit bunch (EFB), mesocarp fibre (MF), palm kernel shell, and palm oil mill effluent (POME).

Anaerobic digestion of EFB, MF, and POME

The sustainability and circularity of the production of palm oil can be improved by anaerobic digestion of EFB, MF, and POME. Anaerobic digestion experiments with untreated and steam treated EFB and MF were performed. It was experimentally proven that steam treatment of EFB and MF improves the anaerobic digestibility of these residues. Alternative conceptual palm oil mill set-ups, including anaerobic digestion, were analysed on techno-economic, environmental, and circularity aspects.

Scenario analysis

Four palm oil mill set-ups were defined:

- Base case: Combustion of MF (and 13% of shell) for steam generation, electricity from the grid, EFB is returned to plantation as mulch, POME is treated in open ponds and the sludge and effluent are returned to the plantation.
- Case 1: Same as the Base case except POME is anaerobically digested in covered lagoons and the collected biogas is used to generate electricity.
- Case 2a: Besides POME, also EFB and MF are anaerobically digested in covered lagoons and the collected biogas is used to produce both steam and electricity.
- Case 2b: Same as Case 2a except the EFB and MF are steam treated before they are anaerobically digested.

The composition and size of the input and output streams were determined and for all set-ups the mass, mineral, and energy balances were obtained. The assumptions are based on literature, experimental data from Colombian palm oil mills, quotes from Colombian equipment suppliers, and expert knowledge of Cenipalma and Wageningen Food and Biobased Research.

Techno-economic analysis

Table 1. Economic indicators. The steam treatment in Case 2b makes a significant difference in the fixed capital investment. Purchasing electricity from the grid in the Base case compared to selling electricity in the other cases, makes a significant difference in the average cash flow.

	Base case	Case 1	Case 2a	Case 2b
Fixed capital investment	21.4	22.1	22.0	23.6
Average cash flow (M$/y)	3.4	4.1	4.1	4.2
Simple pay-back period (y)	6.2	5.4	5.4	5.6
Net present value (M$)	9.6	15.0	14.7	14.5
Internal rate of return	10%	14%	13%	13%

GHG emission performance

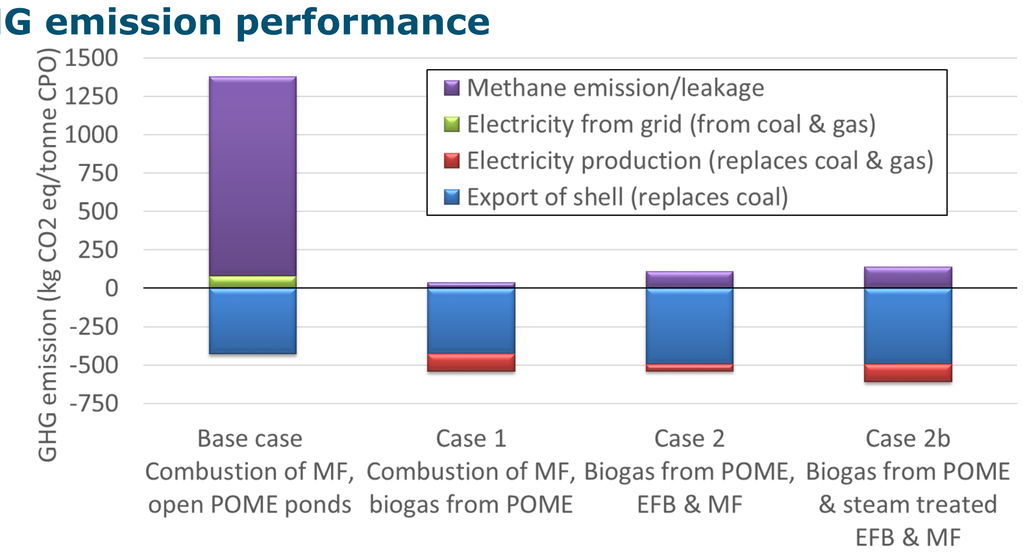

Figure 1. GHG emission performance of the defined cases. The methane emission from the open POME ponds in the Base case is by far the largest contributor to the GHG emission. Generating electricity from biogas (Case 1, 2a, and 2b) has, compared to getting electricity from the grid in the Base case, a relatively small effect on the GHG emission performance.

Circularity performance

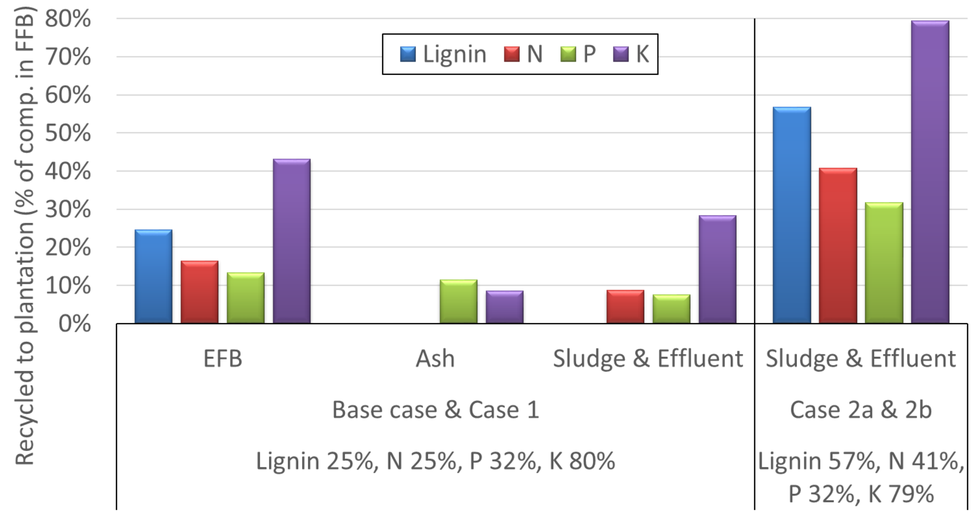

Figure 2. Circularity performance, the totals are given below the X-axes. The main difference is caused by the use of MF in the biomass boiler in the Base case and Case 1. By burning the MF, the lignin and N can not be recovered. By anaerobic digestion, in Case 2a and 2b, the lignin and N are preserved in the sludge and effluent.

Conclusions

- It was experimentally proven that steam treatment of EFB and MF improves the anaerobic digestibility of these residues.
- The biogas from the EFB, MF, and POME can provide enough energy to be self-sufficient in steam and electricity.
- If the steam boiler runs on biogas instead of biomass, no cyclone and electrostatic filter are required for emission control, which equalizes the fixed capital costs related to a biogas system.
- Preventing methane emission from open POME ponds drastically decreases GHG emission.
- The nutrients and recalcitrant organic matter are preserved in the sludge and effluent, which can be returned to the soil of the plantation.

Acknowledgements

This project has been partially financed through the BO-43-003.02-017 “Sustainable Palm Oil Colombia” project, financed by the Dutch Ministry of Agriculture, Nature and Food Quality, and partially by the Colombian Oil Palm Development Fund. A Knowledge to Knowledge (K2K) agreement is established between Wageningen University and Research and Cenipalma. The K2K aims to boost a circular economy in the palm oil sector. It addresses efficient use of land, nutrients, and biomass. The objective is to increase circularity of resource use on the field and in the palm oil mill.

Wageningen Food & Biobased Research
P.O. Box 17, 6700 AA Wageningen, The Netherlands
Contact: julien.voogt@wur.nl
www.wur.nl