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Greenhouse gas reductions through enhanced use of residues in the life cycle of Malaysian palm oil derived biodiesel

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ABSTRACT

This study identifies the potential greenhouse gas (GHG) reductions, which can be achieved by optimizing the use of residues in the life cycle of palm oil derived biodiesel. This is done through compilation of data on existing and prospective treatment technologies as well as practical experiments on methane potentials from empty fruit bunches. Methane capture from the anaerobic digestion of palm oil mill effluent was found to result in the highest GHG reductions. Among the solid residues, energy extraction from shells was found to constitute the biggest GHG savings per ton of residue, whereas energy extraction from empty fruit bunches was found to be the most significant in the biodiesel production life cycle. All the studied waste treatment technologies performed significantly better than the conventional practices and with dedicated efforts of optimized use in the palm oil industry, the production of palm oil derived biodiesel can be almost carbon neutral.

1. Introduction

Palm oil is the biggest vegetable oil in the world with a 2009 market share of 31.7%, which increases to 35.4% with the inclusion of the co-product palm kernel oil (MPOB, 2010). In Malaysia oil palm plantations take up 14.3% of the total land area with an average and relatively constant growth rate of 3.9% from 2005 to 2009 (MPOB, 2010). The production of 17.6 million tons of crude palm oil (CPO) and 2.1 million ton crude palm kernel oil, CPKO, in 2009 (MPOB, 2010) makes the palm oil industry the fourth largest revenue sector in Malaysia in 2009 with a gross national income (GNI) contribution of USD 17 billion after oil and gas (USD 36 billion), financial services (19 billion) and wholesale and retail (19 billion) (PEMANDU, 2011). In 2009 Malaysia exported 227,457 tons palm oil derived biodiesel (MPOB, 2010). Apart from ensuring sustainable land use change, the use of residues for optimal environmental performance in the life cycle of palm oil biodiesel production is one of the most important criteria in ensuring sustainable palm oil.

The aim of this paper is to evaluate the significance of technological improvements on the greenhouse gas (GHG) balance in handling of residues from palm oil and biodiesel production compared to conventional practices. This is done through application of life cycle assessment (LCA) tools. A brief background literature review is given in Appendix 1 of the Supplementary data.

Among the various waste treatments available, this study focuses on technologies, which are available for full scale implementation and that provide energy recovery (electricity, steam, etc.) or carbon sequestration. The chosen technologies, hereafter termed 'prospective technologies' are thus: (1) incineration with energy recovery, (2) pyrolysis, (3) biogas. As such it is not the aim to create a utopian best case scenario, but rather to assess the conventional residue use and disposal as well as realistic improvements to these conventional practices. A flow diagram identifying the conventional practices, prospective technologies and qualitative emissions/benefits of the various treatments is provided in Fig. 1 in Section 3. It should be noted that all four technologies have already been implemented full scale in the Malaysian palm oil industry, but only in very few cases as of primo 2011. The conventional practices are not a worst case scenario. Except for the palm oil mill effluent, POME, all residues are generally used, thus creating very little actual waste through low-tech application. In a worst case scenario, all residues would be landfilled in open dump sites. The implementation of the prospective technologies is unlikely to be a best case scenario. It is likely that some residues can be refined to replace products, which are very energy intensive to produce and thus create larger GHG savings than the three relatively low-tech prospective technologies included in this study.

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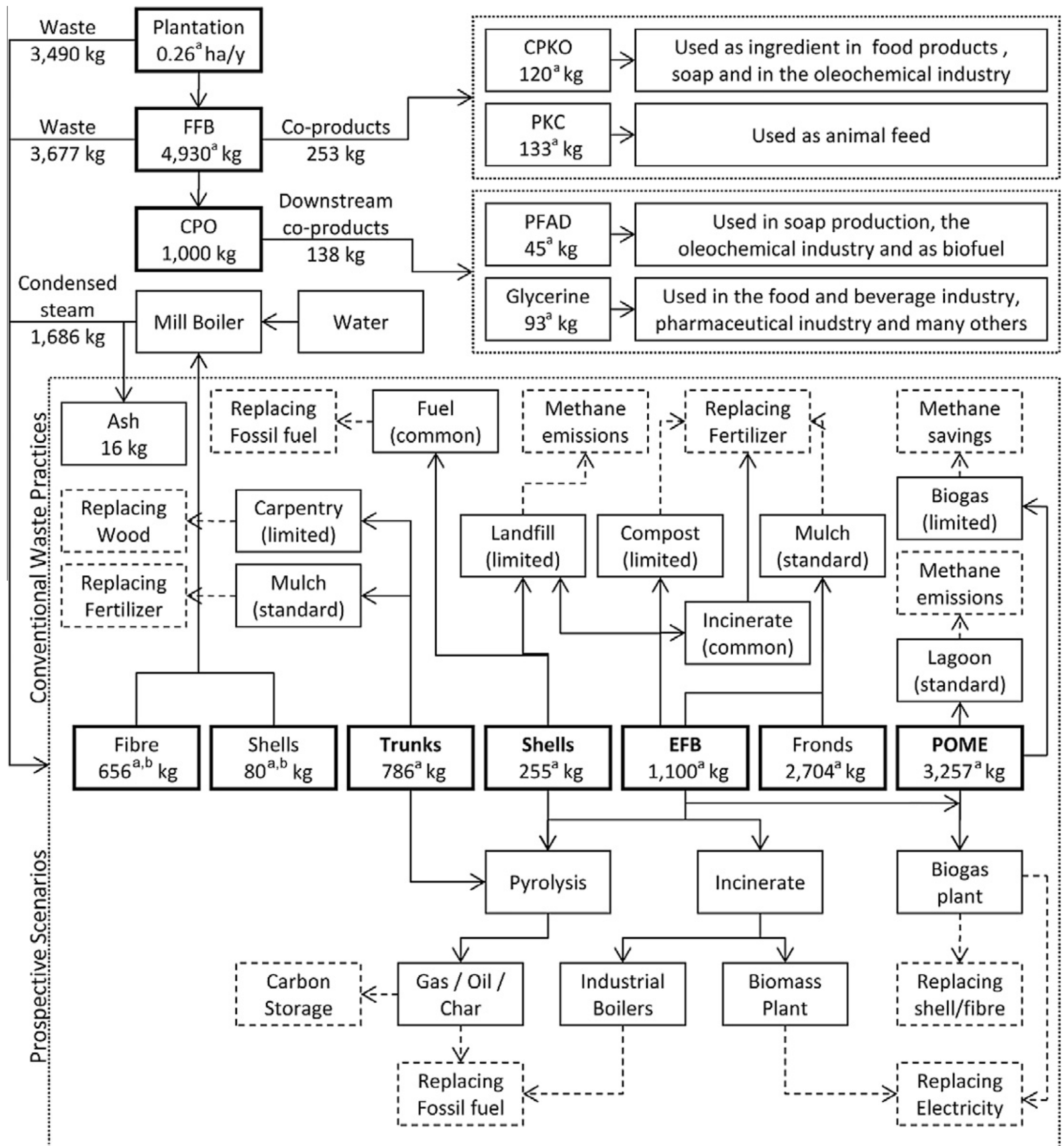

Fig. 1. Conventional practices and prospective technologies. (a) All quantities are wet weight averages from MPOB (2010), Felda (2010), Schmidt (2007), Subramaniam et al. (2008), Wicke et al. (2008), Yusoff (2006). Please find references for the uses in the following sections on the respective treatment technologies. For details from the individual studies and for an easy overview of the residue quantities, please refer to Appendix 2 of the Supplementary data. (b) Fiber is depicted as being fully utilized in the mill boiler. That is not conventional practice, but it is applied in this study. Also, approximately half of the shells are currently used in the boilers, not only 80 kg. See Section 3.1 for explanation.

In order to quantify the scale of the benefits from residue utilization in relation to the overall GHG emissions from palm oil derived biodiesel, the GHG emissions/reductions from the conventional and prospective treatment technologies are identified and compared to life cycle emissions for palm oil derived biodiesel. A scenario of the conventional practices is created and compared to a scenario of prospective treatment technologies thus presenting the actual benefits of the prospective residue utilization. In order to assess the sensitivity and uncertainty of the findings, the results and assumptions for each treatment technology (conventional and prospective) and the full scenarios as well as worst and best case scenarios will be assessed and a potential bandwidth for GHG emissions/reductions will be established. The sensitivity for the prospective scenario is given special attention.

Capturing the vast amounts of methane from the anaerobic digestion of palm oil mill effluent (POME) through the construction of biogas plants is recognized as one of the most important environmental challenges in the production of palm oil. It is hypothesized that adding solid residues, e.g. from empty fruit bunches (EFB), to the POME would boost the methane production in the biogas plant thus allowing for increased electricity production from combustion of the methane in gas engines at little extra cost. Experimental studies of biogas production from EFB were performed to test this hypothesis.

To the knowledge of the authors, the present study is the first to attempt to quantify and compare GHG emissions/reductions of various palm oil waste treatment technologies in a life cycle perspective. Industry specific data for this kind of studies are sparse and to some extent inconsistent as of primo 2011. As such, this study should be seen as an introduction to life cycle assessments of waste treatment in the palm oil industry and a platform on which to extend further studies on the topic.