BREAKTHROUGHS IN BIOFUELS; Mobile Technology for Biodiesel Production from Indonesian Resources

Summary

The proposed research project concerns the development of a local/community-scale biodiesel industry and waste products thereof in Central/South Kalimantan area to

- Stimulate the local economy and particularly local agricultural activities
- Prevent further degradation of the environment and particularly that of sensitive peatlands
- Reduce the chances of forest fires leading to haze problems throughout South East Asia
- Stimulate the transition of Indonesia into a biobased economy
- Reduce the Indonesian dependency of fossil resources like crude oil

By means of

- Use of (purified) Pure Plant Oils from local resources (rubber seed oil, palm oil, and possibly in the near future also Jatropha oil)
- Development of mobile biodiesel technology using acid/base catalysts as well as home-made lipases (e.g. using enzymes extracted from germinating Jatropha Curcas seeds) in highly integrated reactor/separator devices using methanol or locally produced bio-ethanol
- Development of technology for the valorization of protein by-products with an emphasis on livestock feed and biofertilizer to improve the soil structure and reduce dependency of expensive fertilizers
- Development of models for mobile processing units for multiple products (with limited shelf-live and/or optimal harvesting moment) and multiple end products to optimize production capacity
- A local economic resource development (LERD) program, establishment of a framework and concrete action plan for all stakeholders involved in the introduction of new technology including local government planners, small entrepreneurs and NGO?s and creating a conducive environment.

The integrated interdisciplinary project will be carried out by 6 universities (three in Indonesia, three in the Netherlands) and is divided into 7 discrete subprojects, to be carried out by four Indonesian sandwich PhD students and two postdoctoral fellows (one from Indonesia and one Dutch). In addition, the involvement of Indonesian master students participating in existing (double degree) master programmes as well as Dutch master students is foreseen.

Support for budget extension may come from the RUG Bernoulli PhD Programme, and possibly Indonesian sources such as the DIKTI's BPPS Scholarship programme and research grants by the Ministry of Research and Technology. In the framework of INHEP financial support from own university funds (up to 300.000 euro) has been committed by the rectors of ITB and UGM during their visit to the Netherlands recently to be used for additional PhD studies under the umbrella of ABF.

Techno-economic evaluations on seed processing technology

Name promoter/supervisor: Prof.dr.ir. A.A. Broekhuis (RUG), Dr.ir. S.A.R. Kersten (UT), Dr.ir. R. Manurung (ITB).

Research School: RUG, UT, ITB

Summary

Objectives:

- Techno-economic evaluation on seed processing units for oil seeds
- Selection of preferred seed processing technology for Kalimantan ex-Mega rice area

Introduction:

Both the quantity and quality of the pure plant oil that can be isolated from oil-containing biomass resources depends on several factors. Parameters such as plant species, climate and soil conditions, and harvesting and product storage procedures are known to affect the quality of the biomass feedstock before oil extraction. Next the technology used to isolate the desired oil from the feedstock, the subsequent oil work-up procedures and the storage of purified oils are known as additional variables that determine product yield, product quality and product consistency.

For large volume commercial food-related oils, such as sun-flower oil, palm oil or soybased oils, the critical parameters are known and the oil extraction and work-up procedures are well developed. However, for abundantly available oil-containing feedstocks that do not interfere in the food-chain, such as rubber tree (Hevea Brasiliensis) and Jatropha curcas seeds, growth conditions, harvesting procedures have not been optimized, and oil extraction technologies are not yet developed.

In this project, which will focus on the use of the latter feedstocks, the currently available know-how on feedstock treatment, crude oil composition and conversion technology into biodiesel will be reviewed. This information will be used in combination with know-how available for common commercial vegetable oils to select and apply suitable extraction, work-up and storage procedures for rubber tree and Jatropha seeds. The obtained oils will be evaluated as pure plant oils oil and their biodiesel (alcohol-ester) derivatives against familiar fossil-oil based diesel specifications. This evaluation will include a manufacturing and supply chain cost analysis.

Exploratory studies on biodiesel synthesis in mobile production units using centrifugal contactor separators

Name promoter/supervisor: Prof.dr.ir. H.J. Heeres (RUG), Dr.ir. R. Manurung (ITB)

Research School: RUG, ITB

Summary

Objective:

- Demonstrate the use of highly integrated CCS equipment for the continuous production of purified biodiesel from methanol and ethanol on laboratory scale

Introduction:

Biodiesel is currently produced on commercial scale mainly in batch operation using either basic (e.g. NaOH, NaOMe) or acidic catalysts (e.g. sulphuric acid). We have recently reported interesting leads for the continuous biodiesel manufacture in a highly integrated CCS of the type CINC-V02, although significant improvements are required to a commercialization stage. In the CCS device reaction and separation are combined in a single apparatus, thus making it a good example of process intensification (PI). The CINC V02 (Fig. 1) is basically a rotating centrifuge in a static reactor housing. The immiscible liquids (here methanol/ethanol and a pure plant oil) are fed to the side of the CCS where they are dispersed in the annular zone between the static housing and the rotating centrifuge. The dispersion is then transferred into the hollow centrifuge, through a hole in the bottom plate, where the immiscible products phases (here biodiesel and glycerol) are separated by centrifugal forces of up to 900 g, making it possible to separate fluids with densities that differ only 10 kg·m-3. Both liquid phases are collected individually, making use of a weir system.

Fig. 1. Schematic cross-sectional view of the CINC (courtesy of Auxill, The Netherlands).

At optimum conditions a reproducible biodiesel yield of 96 % was achieved using a basic catalyst. Due to the compact size and flexibility in operation, the CCS equipment is likely very suitable for biodiesel production in mobile units. A cascade of two CINC's in series, one for biodiesel production and one for a subsequent aqueous wash to remove remaining glycerol and catalyst followed by a methanol stripper is a very attractive process option. We here propose to perform experimental studies to

- Determine the potential of a single CCS device for the synthesis of biodiesel from pure the locally produced plant plant oils (PPO) and methanol/ethanol using basic (for PPO with a low free fatty acid (FFA) content) and acid catalysts (for high FFA PPO's)

- Optimisation of the volumetric biodiesel production rate (kg/m3reactor.h) by process studies and hardware modifications

- Determine the potential of a cascade of two CCS devices, one for biodiesel synthesis and one for the subsequent biodiesel wash to remove catalyst residues and methanol, preferably using ethanol, but with methanol as the fall back option.

Techno-economic evaluations of biodiesel synthesis inmobile production units using centrifugal contactorseparators (CCS)

Name promoter/supervisor: Prof.dr.ir. A.A. Broekhuis (RUG), Dr.ir. S.R.A Kersten (UT), Dr.ir. R. Manurung, (ITB) Dr. ir. Y.Sulistyanto (CIMTROP)

Research School: RUG, UT, ITB, CIMTROP

Summary

Objectives:

- Techno-economic evaluation of the use of CCS technology for biodiesel synthesis inmobile units

Introduction:

On the basis of the input from project 1 from this proposal in which an overview and selection of candidate production technologies for use in medium scale (skid-mounted) mobile biodiesel production units is made, a cost analysis will be made for current commercial technologies. This analysis will be taken as the reference case for a value assessment of the proposed innovative technology presented in project 2.

Recent work provided interesting leads and a preliminary proof of principle for the continuous biodiesel manufacture in a highly integrated CCS of the type CINC-V02 (Kraai et al. (2008). Using (small) laboratory bench-scale equipment, it was found that at optimum conditions a reproducible biodiesel yield of 96 % could be achieved using a basic catalyst. Due to its compact size and flexibility in operation, the approach of using CCS equipment is likely very suitable for biodiesel production in skid-mounted mobile units. A cascade of two CINC's in series, one for biodiesel production and one for a subsequent aqueous wash to remove remaining glycerol and catalyst followed by a methanol stripper is a very attractive process option.

We here propose to prepare a basis of design and a preliminary design that can be used to perform a techno-economic evaluation of the mobile CCS technology for biodiesel synthesis.

Development of technology for biodiesel production using locally produced enzymes

Name promoter/supervisor: Prof.dr.ir. H.J. Heeres (RUG), Dr. Ir. Chusnul Hidayat (GMU), Dr. Ir.Pudji Hastuti, MSc (GMU)

Research School: RUG, GMU

Summary

Objectives:

- Identification of suitable enzymes (lipases) from local resources for biodiesel synthesis
- Development of technology for production of re-useable enzymes
- Development of technology for biodiesel synthesis using locally produced enzymes from local resources (batch and continuous)
- Demonstration of concept in CCS devices
- Techno-economic evaluation to assess the potential of the technology

Introduction:

Biodiesel is currently produced on commercial scale using either basic (e.g. NaOH, NaOMe) or acidic catalysts (e.g. sulphuric acid). The use of enzymes for biodiesel production has several advantages. For instance, the neutralization step of the traditional catalysts leading to solid waste and expensive solid waste handling is not required.

However, enzymatic biodiesel technology has not been commercialized to date, mainly due to high enzyme costs. We here propose to reduce enzyme costs by using cheap and locally produced enzymes from cheap renewable resources available in Indonesia (e.g. germinating seeds of a.o the Jatropha plant, rubber plant and nyamplung plant; fungi using solid state fermentation) combined with the use of CCS technology.

We have recently discovered indigenous lipases from germinated Jatropha seeds, papaya latex, rice bran and fungi (Hidayat et al, 2005; Hidayat et al., 20008; Hastuti et al, 2006). The use of CCS equipment for classical biodiesel synthesis using a basic catalyst has been proven recently in our group and shown that the productivity outperforms classical batch processes (Kraai et al. (2008) Angew Chem Intern Edit 47: 3905-8).

Furthermore, enzyme catalysis also proved well possible in the devices. High enzyme turnovers could be achieved using smart enzyme recycling strategies, leading to reductions in enzyme costs.

Optimal planning and control of mobile processing technology with multiple inputs and outputs

Name promoter/supervisor: Prof. dr. M. van der Vlerk (RUG), Dr. D. P van Donk (RUG), Dr.ir. Togar M. Simatupang (ITB)

Research School: RUG, ITB

Summary

Objectives:

- Review of current approaches for mobile processing units that incorporates uncertainties in agricultural and production systems. This also includes possible conflicts taken place among different stakeholders in decision making process.
- Development of case study protocols and analysis of local cases.
- Development of suitable models and algorithms for optimal planning and control of mobile processing technology.

Introduction:

This project builds on different streams in the literature: campaign planning literature, uncertainty in yields and incorporating decay of natural materials in operations management research.

Campaign planning literature (e.g. Everingham et al., 2002; Grunow et al., 2007) will be used to develop tools for cultivation planning. Additionally, the usage of different inputs and the establishment of appropriate sizes of areas are investigated as well. Different from the standard campaign planning literature is that supply to a mobile unit is from within one area only. It is likely that insights from scheduling harvesting machines can be beneficial in developing part of our models (see e.g. Higgins, 2006; Higgins et al., 2004).

So far, the use of mobile processing units has not been investigated in this area Natural circumstances and decay during harvest, transport and storage will influence the quality of the input raw materials and as a consequence influence the processing time and yields (Everingham et al., 2002). Determining the optimal sequence of areas to be harvested and processed is one of the means to reduce such losses. Results from food chemistry (e.g Labuza, 1982) with respect to decay and loss of quality of food and natural products have hardly been incorporated in the field of operations and logistics vis a vis in the campaign planning literature. These insights will be used to develop models that will help to find an optimal route for the processing unit.

As the processing unit needs to work continuously, some storage of raw material is needed, but given uncertainties in yield in terms of amount and quality in an area, uncertainties in harvesting and transportation to the unit, it is difficult to determine the amount of required inventory. Goyal and Giri (2001) review the extensive literature on inventory management and storage in case of uncertainty in yields. Part of that rather theoretical work will be useful in analyzing the above sketched problem.

In this project we will address the following research subjects:

- Cultivation planning for multiple interrelated areas with multiple products and several types of demand that need to be satisfied at a yearly level.
- Planning of the harvest which is mainly the determination of the subsequent areas to be reaped.

This includes the planning of the mobile unit and possible transport of raw material to and of final products from that unit. At this intermediate level uncertainties are already incorporated related to yield and quality to attain a robust plan. An interesting sub problem here is to determine the capacity of the processing unit and determine possible trade-offs between increased efficiency with other cost components as transportation, movement of the unit, start-up of the unit etc.

Finally, the short term planning is investigated. This plan relates to the day-to-day processing and moving of the mobile unit and its supply (including inventory of raw material and detailed harvesting plans), based on the realization of uncertainties, mentioned earlier.

As a benchmark we will also develop these plans based on a single central processing unit to examine advantages and disadvantages along a number of criteria such as costs, timeliness, sustainability, and quality of products (see e.g. Gunnarsson et al., 2008). There are three distinctive contributions of this project:

- it adds insights from shelf-live and yield literature to campaign planning;
- it considers mobile processing units in campaign planning; and
- it considers multi-product campaigns with more outputs.

The methodology of this study will be a combination of literature study to integrate different streams, field work to gather empirical data, modelling and probably simulation to further understand the working of this system and come up with practical implications and recommendations for policy makers.

Isolation and valorization of peptides and amino acids from the rubber, oil palm- and Jatropha tree

Name promoter/supervisor: Prof.dr. J. Sanders (WUR), Drs. W. Mulder (WUR), Dr.ir. E. Ratnaningsih (ITB).

Research School: WUR, ITB

Summary

Objectives:

- To isolate the proteinaceous fractions from rubber seeds, oil palm, and Jatropha residues after the isolation of their primary products in small scale biorefinery units

- To reduce the chemical and energy inputs for these processes
- To enable small scale operations enabling the recycling of minerals and water
- To study the applications with the highest value in the rural economies

Introduction:

The oil production from the rubber tree seeds, oil palm or Jatropha results in waste streams that contain protein. The aim of this sub project is the utilization of these protein fractions for applications that are suitable for the Indonesian society. In this aspect the use in animal feed is one of the most interesting applications. When these protein fractions are used as feed additive, probably the most economical and technical feasible approach is to hydrolyze the proteins followed by extraction from the biomass. In addition, the protein from the rubber extraction from latex will be in the water stream and has to be recovered by coagulation as has been described by Hulst et al (1999).

Small scale biorefinery units (Sanders et al (2002) , Sanders et al (2008) will enable the recycling of minerals and water without much costs.

In principle, proteins can be chemically (acidic or alkaline) or enzymatically hydrolyzed (F Coward-Kelly, 2006). Protein complete hydrolysis into amino acids required more severe conditions, such as heating proteins for 24 hours at 110°C in 6 N HCl. But even under such severe conditions, some peptide bonds, like valine-valine and isoleucine-isoleucine, will not be cleaved. Nearly complete hydrolysis under alkaline conditions is possible at 100°C, 5 N NaOH during 18-24 hours. The disadvantage of alkaline hydrolysis is the formation of lysoalanine which is not allowed for food applications. Besides chemical hydrolysis, the molecular weight of proteins can also be decreased by the use of proteases. Basically, enzymes can hydrolyze a protein in two ways; exoenzymes can sequently remove single amino acids from the end of the protein chain, whereas endoenzymes can rupture the internal bonds in a random manner at any point along the chains. To achieve high degrees of hydrolysis often combinations of exo and endoproteases/ peptidases are used.

To produce hydrolysates with a high degree of hydrolysis, both the chemical route, the enzymatic route, and also its combination will be investigated.

- Organic acids like fumaric acid, maleic acid, propionic acid and acetic acid will be utilized in hydrolysis. In this way the drawback of hydrolysis under alkaline or acidic conditions (being that a lot of salt is being trapped in the amino acids/peptides after recovery) is overcome, since the organic acids can be fed to animals together with the amino acids/peptides extracted. The cost for the organic acids is a lot higher than for mineral acids, so we would like to investigate whether and to which extend the organic acids can be recovered for a second use by extraction technologies. In addition, the severe conditions of the chemical hydrolysis can cause damage of certain amino acids. A non-conventional technique to hydrolyze proteins, by the use of solid acid catalysts (hydrotalcites) is a promising option as it will not require the use of corrosive mineral acids. In this way, also less salt is being generated and isolation of the amino acids is facilitated. In order to use solid bases or acids, protein solubility is required. This can be achieved by mild acid, base or enzymatic treatment.

- Mixtures of different enzymes will be used, but also cascade processes, in which addition of series of proteases differing in specificity and optimal conditions. With respect to the hydrolysis of proteins to produce amino acids, the chemical pathway is cheaper. However, enzymatic methods become attractive in case of cheaper production methods or the development of less specific enzymes could be developed. Immobilisation of enzymes might also enhance the economic feasibility.

- A process on small scale is envisaged. We have to investigate certain equipment suitable for such process. This will depend on the chemicals/enzymes that give the right hydrolysis patterns on laboratory scale.

Apart from direct application in animal feed we want to explore the isolation of specific amino acids from the hydrolysates by extraction technologies for a variety of applications. For a good application in feed, the level of hydrolysis is not important. However, for the extraction of pure aminoacids the level is very important when high yield are required. For feed applications (pigs and poultry) lysine, methionine, threonine and tryptophan are interesting in the order given. Other applications such as building blocks for the chemical industry (Scott et al (2007) are envisaged.

Local Economic Resources Development (LERD)

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Research School: RUG, ITB, CIMTROP

Summary

Rationale:

Most technical improvements in the field of ABF will be applied to and/or change/improve the lives of farmers, small entrepreneurs and possibly medium-size private-sector companies. In the current socio-economic framework, projects in this field, especially in remote areas require a well planned co-operation between all local stakeholders, including the local government. Based on an initial feasibility research aimed at establishing the proper starting conditions in the public/private setting, two LERD trainings will be executed.

Objectives:

The purpose of this component is to build up the economic capacity of a local area, to improve its economic future and the quality of life for all (by means of social and economic entrepreneurship capability development).

Introduction to the LERD training:

The LERD program has been developed by the University of Groningen and ITB based on the Local Economic Development (LED) framework of the World Bank, at the request of the Indonesian National Planning Agency Bappenas. It offers local government, private and not-for-profit sectors, and local communities the opportunity to work together to improve the local economy. It focuses on enhancing competitiveness, increasing sustainable growth and ensuring that growth is inclusive. LED encompasses a range of disciplines including physical planning, economics and marketing, as well as suitable business systems. It incorporates local government and private sector functions including regional and environmental planning, business development, infrastructure provision, real estate development and finance.