Valorisation of Indonesian renewable resources and particularly *Jatropha curcas* using the BIO-REFINERY concept

Netherlands Programme Coordinator: Prof. Dr Ir HJ Heeres (RijksUniversiteit Groningen - RUG, Stratingh Institute)
Indonesian Programme Coordinator: Dr Ir R Manurung (Bandung Institute of Technology - ITB / Centre for Biotechnology)

Main Summary
This priority program proposal covers the valorisation of Indonesian renewable resources, in particular the tree *Jatropha curcas*, by application of the bio-refinery concept. The tree can be cultivated in harsh climatic tropical regions and is historically known for its toxic nature, but at the same time, as an attractive source for pharmaceuticals. More recently, the tree has been recognised as a source for medium viscosity pure plant oil (PPO), which successfully has been tested as fuel in stationary diesel engines. Because of its toxic nature and excellent growth characteristics in the Indonesian climate, oil production from the seeds of this plant is considered to be an attractive source of bio-fuel that can reduce the dependency of Indonesia on fossil-oil imports. This without competing with the local and regional food oriented plant-based oil production industries, like palm oil. Besides PPO extracted from the seeds, the tree produces proteins (seed residue), carbohydrates (fruits), lignocelluloses (seed hulls, leaves and branches) and plant juices. Moreover, large-scale cultivation of *Jatropha curcas* will benefit the socio-economic circumstances in rural Indonesian areas as it generates several new employment opportunities.

The proposed program aims to research the potential exploitation and valorisation of the full tree by application of the bio-refinery concept. Several work-packages have been defined to research and evaluate all the different products that can be derived from this natural resource. The packages cover:

- Economic and socio-economic analysis, and, definition of the optimum cultivation and production configurations
- Optimisation of the oil extraction process and process/product development to obtain consistent and high quality fuel oils
- Research and development of new technology to derive a new type of bio-diesel without the need to convert the PPO into bio-diesel (i.e. without conversion to ethanol or methanol esters)
- Chemical modification of PPO into new bulk and specialty chemicals
- Exploration of the plant constituents to develop new pharmaceutical products
- Oil extraction and detoxification by the use of a fungus
- Microbial treatment of the seed residue (primarily proteins) for energy and feed production
- Non-food valorisation of bio-refinery waste streams
- The development of efficient direct somatic embryogenesis of the *Jatropha curcas* plant

The breadth in scientific disciplines required for this bio-refinery approach is a major challenge for the successful execution of the proposed program and the subsequent initiation of large-scale cultivation of the *Jatropha curcas* plant. To cover the required disciplines, a consortium has been built such that all required know-how and resources are available to the project. Two Dutch universities, i.e. the Rijksuniversiteit Groningen (RUG, Chemical Engineering Department, Pharmaceutical Biology Department, and the Institute for Technology and Management), the University of Wageningen (WUR, Agro-technology & Food Innovations, Biobased Products) will
cooperate with two Indonesian Institutes, i.e. the Technology Institute Bandung (ITB, Centre for Biotechnology) and the Agency for the Assessment and Application of Technology (BPPT, Department for Natural Resources Development). Additional support for the project will be obtained from public and governmental institutes and from companies that have an interest in PPO applications and agricultural development.

The applicant from the RUG will coordinate the project and an Indonesian and a Dutch project leader will manage each workpackage. Eight sandwich PHD students and a post-doc, who all will execute part of their work at locations in Indonesia and the Netherlands, will carry out the research proposed in the workpackages. Dissemination of the research results will be covered by public reports, publications in refereed papers, and lectures at conferences, seminars and workshops. This approach guarantees the building of an international network, excellent knowledge transfer and supports the creation and extension of the scientific community in Indonesia.

General evaluations on integrated *Jatropha curcas* production chains using the Bio-refinery concept
Netherlands Project Leader: Prof. Dr AA Broekhuis (RUG)
Indonesian Project Leader: Dr Jana Tjahjana Anggadiredja (Agency for the Assessment and Application of Technology - BPPT)

Summary:
This part of the project involves general evaluations on the integrated *Jatropha curcas* production chain using the bio-refinery concept. The ultimate goal is the identification of the most promising integrated chain for the Indonesian situation. The approach that will be followed includes the generation of a long list of all possible integrated, sustainable production chains. Reduction of these options to a short list will be performed using a qualitative multi-criteria model based on the bio-refinery concept. Model criteria will be the economic potential of the chain, product value, exergy potential, maturity of the proposed technologies and effects on employment. Selection of the preferred integrated production chain from the short list will be carried out using quantitative exergy analysis, techno-economic analysis, and assessments of the ecological and social impact in Indonesia, and market studies.

In addition, literature studies will be performed to reduce the production costs of the *Jatropha curcas* fruit. Aspects to be investigated are variety selection, determination of optimum climate conditions, required soil quality and fertilization requirements and options. Finally, a strategy will be developed covering all parts of the value-chain.

Optimization of the *Jatropha curcas* pure plant oil extraction and purification process
Netherlands Project Leader: Prof. Dr AA Broekhuis
Indonesian Project Leader: Dr Ir R Manurung

Summary:
Preliminary research has shown that the seeds obtained from the plant *Jatropha curcas* contain over 40 % (by mass) of a medium viscosity triglyceride oil that can be used, in its pure plant oil (PPO) state, as fuel for diesel engines. Besides the lipids, the seeds consist of a lignin-based shell and a protein-rich kernel that also contain moisture, carbohydrates and some trace chemicals. So far the literature shows conflicting results on the performance of the oils in terms of fuel efficiency and engine maintenance requirements, which can be attributed to variations in oil quality, applied extraction technology and product handling.
It is the aim of this study to broaden the scope of application for this new type of PPO, to, for example the use as fuel for compression injection diesel engines or as chemical feedstock. Therefore extensive studies have to be carried out in order to develop economically viable, efficient, consistent and sustainable lipid extraction technologies. Methodologies have to be developed to obtain high extraction efficiencies to obtain lipids of a consistent and high quality.

The main objective of the project proposal is the achievement of optimum lipid extraction levels without deteriorating the product performance characteristics as delivered by nature. The second objective is to develop isolation technology that produces pure lipids of consistent and indisputable quality i.e. having a consistent low content of acidic components such as ortho-phosphoric acid derivatives (phosphatides, lecithins or gums). The third objective is to develop extraction and isolation technology that still enables the subsequent use of the protein-rich matrix from which the lipids have been extracted.

These objectives require a study on different technical approaches to liberate the lipids, and the development of processing/product property relationships that enable the design of extraction and purification units that deliver excellent and consistent fuel performance.

Reduction of *Jatropha curcas* pure plant oil viscosity by homogeneous and heterogeneous co-metathesis catalysis
Netherlands Project Leader: Prof. Dr AA Broekhuis
Indonesian Project Leader: Dr Ir IGW Wenten (ITB)

**Summary:**
Preliminary research has shown that the seeds obtained from the plant *Jatropha curcas* contain over 40 % (by mass) of a medium viscosity triglyceride oil that can be used, in its pure plant oil (PPO) state, as fuel for stationary diesel engines. In a direct comparison to diesel fuel is has been found that *Jatropha* oil has a significantly higher flashpoint (240 ºC against 50 ºC for diesel) and a slightly higher density. Other properties like calorific value and cetane numbers are on par, while the low sulphur content of *Jatropha* oil presents a major advantage. The higher flashpoint can be explained by the molecular structure, in particular, the high molecular weight of the triglycerides compared to the average molecular weight of the components contained in diesel. In order to broaden the use of these lipids s fuels, new technology is required to reduce the flashpoint. This potentially can be accomplished by applying familiar co-metathesis technology using low molecular weight olefins (like ethene, propene, butenes or pentenes).

Epoxidised *Jatropha curcas* oil as a building block for novel biobased products
Netherlands Project Leader: Prof. Dr Ir HJ Heeres
Indonesian Project Leader: Dr Ir R Manurung

**Summary:**
Natural oils are important building blocks for the petrochemical industry. We here propose to develop new synthetic methodology for the preparation of *Jatropha* oil derived high added value products. In this way, the value of the integrated *Jatropha* production chain may be enhanced substantially. We intend to perform an experimental program to develop new efficient catalytic technology to prepare epoxidized *Jatropha* oil, which is an important building block for derivatives with interesting properties that may find applications as bio-lubricants, reactive coatings or as an plasticizer for PVC. The potential of these epoxides to synthesize novel fully bio-based products based on starch/*Jatropha* oil and isosorbide/*Jatropha* oil will be explored.
Next to developing new methodology, structures of effective catalysts will be determined and mechanistic aspects related to the catalysts functionality and the oxidative pathway of the fatty acids will be established.

**Exploration of *Jatropha curcas* constituents aimed at the development of new and safe pharmaceutical products**

Netherlands Project Leader: Dr O Kayser (RUG)
Indonesian Project Leader: Dr A Supriyanto (BPPT)

**Summary:**

*Jatropha curcas* belongs to the family of *Euphorbiaceae*, which is known as a plant family with strong pharmacological but also toxic activities. Most of the knowledge is obtained from the traditional use of herbalist and a clear scientific basis for the use of the plant and its oil is still missing. To use *Jatropha* oil and other products in the discussed valorisation process pharmaceutical approaches are of high interest. Besides of the oil other parts (leaves, roots, stems) are claimed to be potent herbal drugs in folk medicines, but the use is not fully understood. But, using the oil and related products requires high safety levels that have also not been fulfilled so far.

To overcome these problems two major research aims will be studied. First, evaluating of acute, chronic toxicity, ecotoxicology, mutagenicity, and carcinogenic activity of the oil, its derived products and all fractionated biomass from the bio-refinery process; second, to compile a monograph for the medicinal and pharmaceutical use of *J. curcas* oil. Main topic is the physicochemical characterization of the fatty oil, phyto-chemical characterization of the oil and all products from the bio-refinery process and determining biological and pharmacological activity for further use in humans.

**Microbial modification of *Jatropha curcas* press cake for energy and feed applications**

Netherlands Project Leader: Dr Ir E de Jong (Wageningen University and Research Center - WUR)
Indonesian Project Leader: Dr E Ratnaningsih (ITB)

**Summary:**

The project focuses on the use of a fungus (*Rhizopus oryzae*) and fungal enzymes to improve the water extraction of oil from *Jatropha curcas* seeds and to decrease the toxicity of the resulting press cake. *R. oryzae* is also capable of producing ethanol under the right conditions. This will be an alternative source for trans-esterification in the production of bio-diesel. The potential of biogas production of the resulting press cake will also be evaluated. A successful project will generate a more environmentally friendly, energy sufficient and added value generating process for the use of *Jatropha* seeds.

**Commercialisation of non-food applications of *Jatropha* proteins**

Netherlands Project Leader: Prof. Dr JPM Sanders (WUR)
Indonesian Project Leader: Dr Jana Tjahjana Anggadireja (BPPT)

**Summary**

Project WP4.2 will concentrate on various fractionation technologies that have been used for other biomass raw materials and adapt/develop novel technology in order to obtain plant fractions that can be applied in industrial applications such as glues, coatings and surfactants and feed (protein), fermentation including ethanol (soluble carbohydrates), fiber boards and composites (press cake), chemicals, pharmaceuticals (peptides and amino acids).
Non-food valorization of the press cake’s waste stream (without SPIN funding)
Netherlands Project Leader: Dr Ir E de Jong (WUR)
Indonesian Project Leader: Dr Ir U Priyanto (BPPT)

Summary
The focus of this project is to make use of specific intrinsic characteristics of the press cake fraction that could generate the highest value addition to this side stream. The fibrous matter can be used for improvement of stiffness and strength properties of fiberboards and composites, while for the lignin fraction its binding properties of fibers and wood particles is of interest.