May, 2013

Gate-to gate
Life Cycle Assessment of EU Oilseed Crushing and Vegetable Oil Refining

Executive Summary

1. Introduction

FEDIOL, representing the EU Vegetable Oil and Proteinmeal Industry, commissioned TU Berlin to conduct a gate-to-gate life cycle assessment (LCA) of EU rapeseed and soybeans crushing and rapeseed oil, soy oil and palm oil refining.

This LCA follows the ISO standards of LCA[1], which describes the stages for an LCA study:

- Goal and Scope
- Life Cycle Inventory (LCI)
- Life Cycle Impact Assessment (LCIA)
- Interpretation

2. Goal and Scope

The goal of this study was to establish a robust and up to date Life Cycle Inventory data-set to assess the key potential environmental impacts of EU rapeseed and soybeans crushing and rapeseed oil, soy oil and palm oil refining.

The results from this study will allow FEDIOL companies to perform site-specific comparisons and can serve as a basis to understand the relative contribution of this sector to potential environmental impacts of the supply chain as a whole. It could also form the basis of future Environmental Product Declarations (EPDs).

The so-called 'system boundary' in this LCA is from oilseeds entering a crushing plant to the refined vegetable oil leaving the refinery. In this 'gate-to-gate' approach only inputs (e.g. raw materials, energy) and outputs (e.g. emissions, waste) associated with the processes within the boundary are included. Upstream activities (e.g. agricultural production, transport and storage or seeds) and downstream activities (e.g. distribution and use) are not part of this study. The system boundary is illustrated in Figure 1 below.

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[1] ISO 14040: 2006 and ISO 14044: 2006

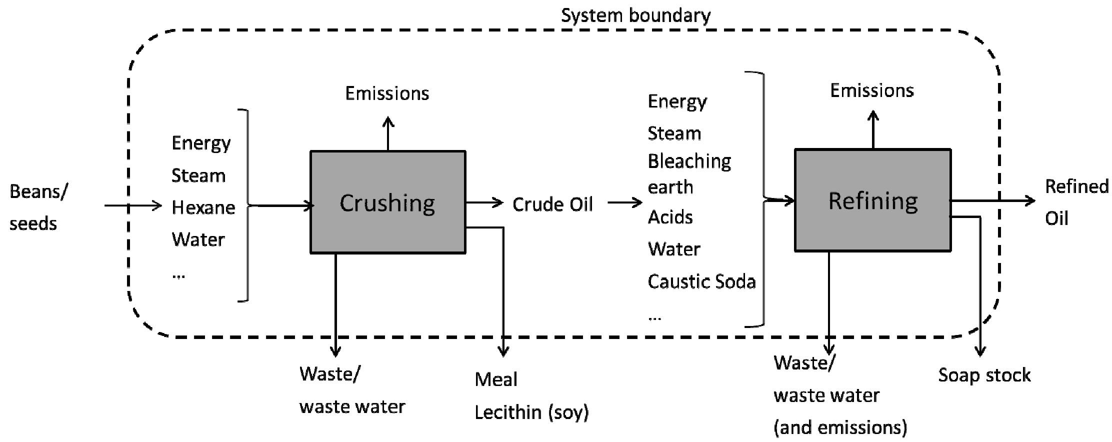

Figure 1: System Boundary : Crushing and Refining

Although during the crushing and refining process several products are produced, as refined vegetable oil is the main product it was decided to use one tonne of refined vegetable oil as the reference unit for expressing inputs, outputs and for assessing potential environmental impacts .

3. Life Cycle Inventory (LCI)

Primary data on crushing and refining was collected from FEDIOL member companies[2] based on more than 20 sites in 6 countries. The data was then weighted according to annual production and used to calculate an average value across all companies. FEDIOL represents 85% of EU capacity and members that provided data in this study cover between 85 and 90% of all FEDIOL activities, so this data can be seen as representative of the crushing and refining industry in the EU.

Given the purpose of this study is to show the average EU situation, rather than be site-specific, and due to limitations on available data, some assumptions and approximations on energy supply and other inputs were inevitable. In these cases widely recognised professional databases were used.[3] Similarly, an average energy mix was calculated based on weighted national crushing and refining data, instead of site-specific energy production.

Certain site-specific elements such as waste, waste-water and associated treatments were excluded from the study as it was impossible to define an average process for them. However, sensitivity analyses were conducted as appropriate.

The use of emission control systems, for example for hydrogen sulphide (H_2S), was not considered therefore values at sites are likely to be significantly lower than those used in the study. It should also be noted that the study assumes all hexane used in crushing is emitted on-site, which will again lead to an overestimation of emissions, but despite this values remain well below legal limits.[4]

Table 1 below summarizes the key data from the LCI relative to the functional unit of one tonne of refined vegetable oil.

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[2] FEDIOL companies providing data: ADM, Bunge, Cargill, IOI Loders Croklaan, Thywissen, Wilmar.

[3] The model mainly used the GaBi 5 professional database. Where this did not have available data the Ecoinvent database was used.

[4] Solvents Emissions Directive 1999/13/EC (1999)

Table 1: Key Average LCI values on the basis of one tonne of refined vegetable oil

	Rapeseed	**Soybean**	**Palm Oil**
	Average	Average	Average
CRUSHING			
Seeds/beans (kg)	2420	5200	
Steam (kg)	590	1300	
Electricity (kWh)	100	150	
Hexane (kg)	1.5	3.0	
Meal (kg)	1390	4080	
REFINING			
Bleaching Earths (kg)	4.0	5.4	12
Acids (sum) (kg)	2.7	3.0	0.85
Sodium Hydroxide (kg)	3.0	2.8	
Steam (kg)	170	225	115
Electricity (kWh)	27	40	29

4. Life Cycle Impact Assessment (LCIA)

The LCIA aims to describe the environmental consequences of the inputs to the environmental burdens quantified in the inventory analysis and to understand and evaluate the size and significance of these potential impacts. The impact assessment was based on the internationally accepted CML method and data[5] and identified the following impact categories as being of relevance:

- Global Warming Potential (GWP)
- Eutrophication Potential (EP)
- Acidification Potential (AP)
- Photochemical Ozone Creation Potential (POCP)
- Ozone Depletion Potential (ODP)

<u>Overview of results:</u>

Figure 2 shows the relative LCIA results of the average EU crushing and refining processing steps expressed per tonne of refined vegetable oil and assuming all potential environmental impacts are associated with the refined oil so assuming no burden on co-products or by-products. For each impact category the relative shares of the potential environmental impacts are broken down by processing step and by type of oil.

[5] Institute of Environmental Sciences, Leiden (CML 2010)

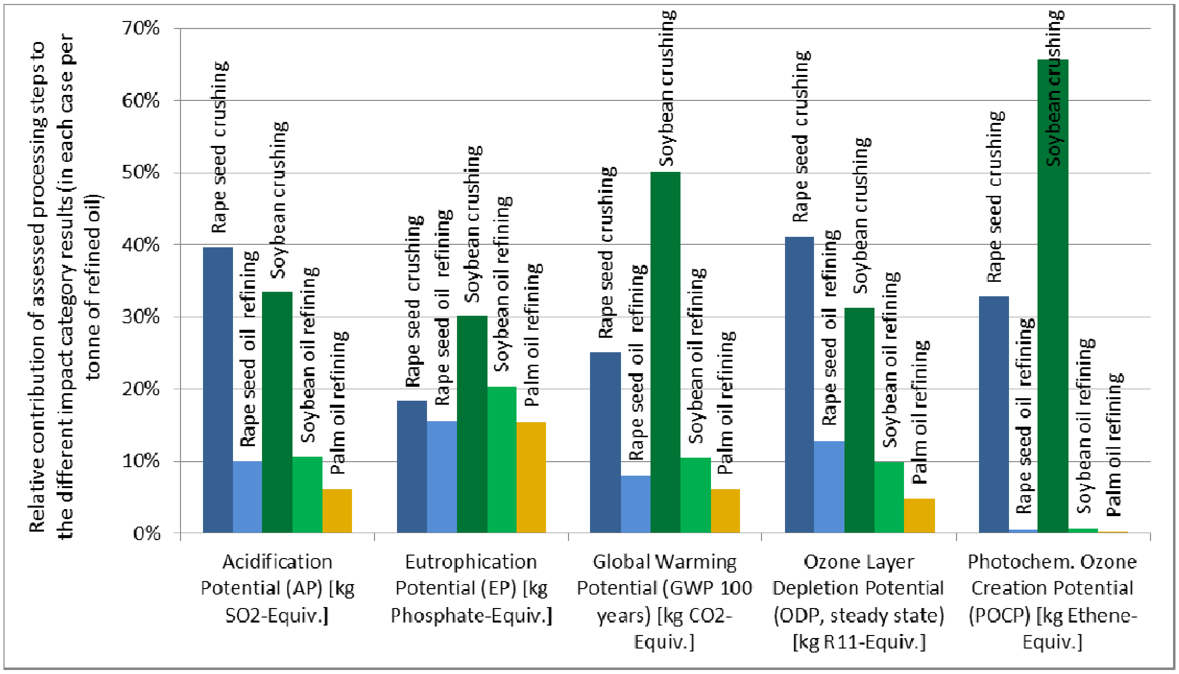

Figure 2: Relative LCIA results for the five environmental impact categories per tonne of refined oil

The results indicate that the potential environmental impact of crushing is greater than refining, mainly because it is more energy intensive. Relative to the functional unit of one tonne of refined oil, across all impact categories considered, the potential environmental impacts of crushing dominate the results. Refining of soybean oil has greater impacts than rapeseed or palm oil. Process steam and electricity production contributed significantly to the potential environmental impacts from crushing and refining.

As crushing and refining produces a number of co-products (e.g. protein meals) and by-products (e.g. soapstocks and fatty acid distillates), potential environmental impacts must be allocated across all the resulting products. ISO 14040-44 sets out a hierarchical approach to allocation. In the first instance, ISO recommends that allocation be avoided if possible by system expansion. ISO then suggests the LCA considers physical allocation such as mass or energy. As a last resort, economic allocation can be considered. Detailed consideration was given to the choice of allocation method. A mass allocation was considered inappropriate due to the relatively large volume of meal, which is the lower value product, compared to the higher value oil product in rapeseed and especially soybeans. Energy allocation was therefore chosen as the most appropriate for this sector. Economic allocation, as the least preferred ISO option, was anyway considered inappropriate for this study due to the price volatility of agricultural commodities.

Using energy allocation, the potential environmental impacts were allocated between the crude oil, meal/cake and lecithin for crushing and the refined oil and soapstock (or fatty acid distillates) for refining, based on energy content (lower heating value LHV).
Figure 3 shows the relative contribution of crushing and refining to the potential environmental impacts based on the functional unit of one tonne of refined oil.

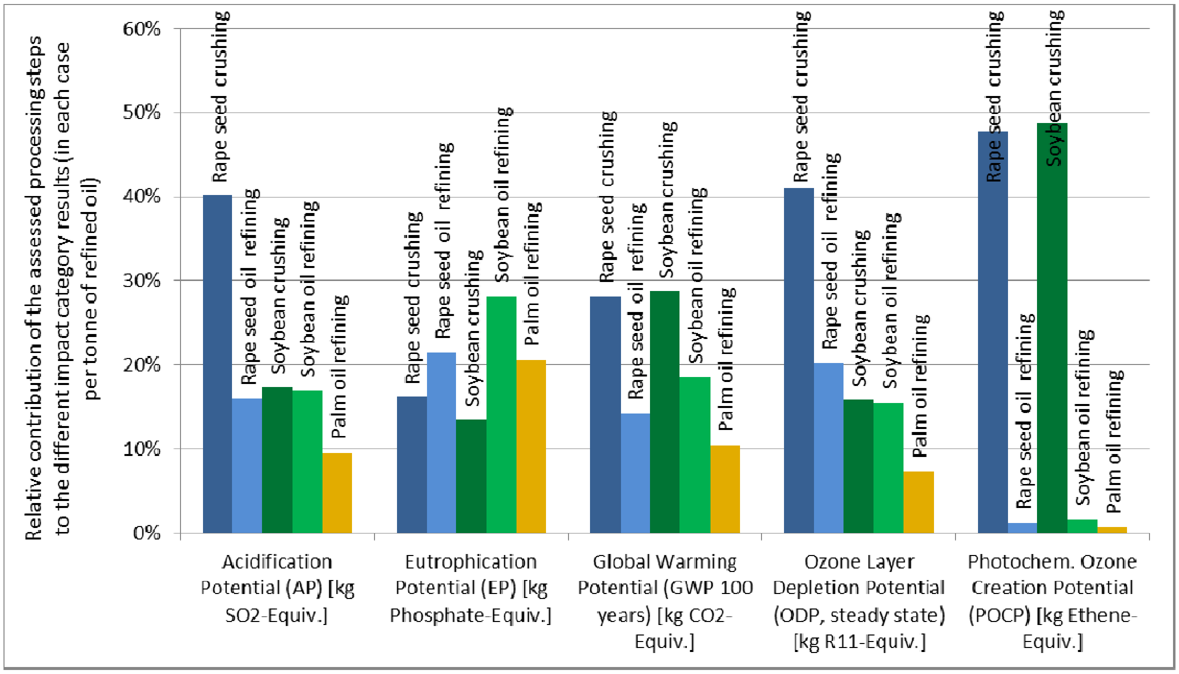

Figure 3: Overview of energy allocation on environmental burden of 1 tonne of refined oil

The results are different to the no-allocation in that the potential environmental impacts of crushing are relatively less significant and the potential impacts of soybean crushing and rapeseed crushing are more evenly matched.

5. Interpretation

During the interpretation of the LCIA, significant issues are identified and the results evaluated. An assessment has been made of the significance of parameters such as the methods chosen. Inputs and outputs with relative high significance for the impact assessment are shown in table 2.

Table 2: Contribution Analysis, overview of relevant inputs and outputs

	Global Warming Potential	Acidification Potential	Eutrophication Potential	Photochemical Ozone Creation Potential	Ozone Depletion Potential
CRUSHING	Process steam	Electricity	Process steam		Electricity
	Electricity	H_2S emissions	Electricity		
		Process steam	Hexane production	Hexane emissions	
REFINING	Process steam	Process steam	Acids production		Electricity
	Electricity	Electricity			

Sensitivity analysis

A sensitivity analysis was conducted to test the robustness of the LCA results. The production of electricity and process steam dominate results across most impact categories. The use of acid oils during refining also showed significance for some impacts, so these were included in the sensitivity analysis. Wastewater treatment was not included in the study as site practices vary considerably making an EU picture impossible to draw, however, it was considered in the sensitivity analysis.

As part of the sensitivity analysis, alternative allocation methods (other than energy allocation) were checked. A mass allocation approach would have significantly reduced the potential environmental impact of refined vegetable oil, whilst an economic allocation would have increased it.

Finally, the sensitivity analysis examined the variation of data and the chosen CML methodology, which is the most common method used in LCA, against the alternative ReCiPe method. A sensitivity analysis is a helpful measure of the robustness of an LCA. With the exception of some data gaps identified, for example on acids used, the data and methodology used were found to be robust.

6. Conclusions and Recommendations

This LCA study establishes a representative an up to date gate-to-gate lifecycle inventory database and evaluates the environmental performance of oilseed crushing and vegetable oil refining in the EU.

The study reveals that air emissions and energy consumption during oilseed crushing are the key contributors to the potential environmental impacts in the LCIA. It also demonstrates that production of some auxiliary material inputs (bleaching earth, acids) used in oil refining contribute to specific potential environmental impacts. FEDIOL member companies could usefully concentrate efforts to reduce potential environmental impacts on improving energy efficiency, reducing emissions of hydrogen sulphide and reducing the use of hexane and acids.

The results of this study can serve as a benchmark for site or company-specific LCAs for FEDIOL member companies and can be used by the supply chain within broader LCIAs. The results can be used as a solid base for further studies for example to assess wastewater and wastewater treatment, acid use and water consumption. This LCA may serve as a basis for the development of product category rules (PCRs) for oilseed crushing and vegetable oil refining. Possible future work could extend the study to include other oilseeds and vegetable oils.