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Life Cycle Inventory for winter and spring rapeseed production in Northern Europe

Anda Fridrihsone [a, *], Francesco Romagnoli [b], Ugis Cabulis [a]

[a] Polymer Department, Latvian State Institute of Wood Chemistry, 27 Dzerbenes str., Riga, LV-1006, Latvia
[b] Institute of Energy Systems and Environment, Riga Technical University, 12-1 Azenes str., Riga, LV-1039, Latvia

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ABSTRACT

Rapeseed is currently cultivated as an industrial crop in Latvia as a source of oil rich biomass to contribute to renewable energy goals of the European Union. However, rapeseed oil can also be used as a feedstock biobased polyurethane production. Latvian State Institute of Wood Chemistry have developed polyols based on rapeseed oil and have developed biobased and volatile organic compounds-free polyurethane coatings.

The main aim of this study was to present a Life Cycle Inventory of spring and winter rapeseed produced in Northern European country Latvia based on primary data of agricultural practices used in this region. The study was carried in accordance with ISO 14040 and ISO 14044. Data were collected from a large crop company in Latvia to ensure a specific and accurate data collection for the definition of the complete supply chain. The reference unit of this study was defined as 1 ha, time horizon 2008–2016, stages from the raw materials production to the seed harvesting were considered. The data presented will add to and expand the existing knowledge of rapeseed production in other European countries.

Lastly, this paper is the first in a series of papers that will result in a complete Life Cycle Assessment for these develop polyurethane coatings based on rapeseed oil polyols to avoid black box unit process and provide transparent results.

1. Introduction

Oil crops are an attractive raw material for the polymer industry and have been studied intensively by both, academia and industry, to find more sustainable feedstock for the industry. Different vegetable oils, such as castor (Mutlu et al., 2010), soybean (Petrovic et al., 2007), palm (Markovich et al., 2017), jatropha (Saalah et al., 2015) and rapeseed (Zieleniewska et al., 2015; Stirna et al., 2014) have been studied as a biobased feedstock for polyurethane (PU) materials. PU is synthesized in a reaction between isocyanate moiety containing isocyanate groups (-NCO) and polyol components containing hydroxyl groups (-OH) (Ionescu, 2005). Due to its versatility, PU is one of the most widely used polymers. The global biobased PU market is expected to reach ~ USD 38 million (Jan 2015) by 2020. The global biobased market was 1634.0 tons in 2013 and is expected to jump to 2546.6 tons by 2020. The building industry is mentioned as the largest end-use industry for the biobased PU market and accounted for 35% of total volume in 2013 (Biobased polyurethane market analysis, 2015).

Furthermore, oil crops are an attractive renewable energy resource even if some are the first generation type of biofuel. Despite being first generation feedstock, different oil crops are intensively used for biodiesel production. Depending on the region, different oil crops are the main feedstock for biodiesel production – in Europe it is rapeseed, which is grown throughout Europe; in the US it is soybean; and palm oil in the Asian region. From 2007 to 2012, EU biodiesel production grew 57%. In 2015, the production of biodiesel reached 11,067,800 tons in 28 member states of the European Union (EU-28), with the majority of production coming from Germany with 2,765,400 tons, followed by France with 2,139,100 tons. Latvia produced 65,700 tons of biodiesel according to Eurostat (2017a). Rapeseed oil is the main feedstock for biodiesel production in the European Union (EU), accounting for 49% of total production in 2015 (EU Biofuels Annual, 2016).

Rapeseed (*Brassica napus*) is a widely cultivated crop around the world due mainly to its oil rich seeds. It is the second largest source

* Corresponding author.
E-mail addresses: anda.fridrihsone@edi.lv (A. Fridrihsone), francesco.fomagnoli@rtu.lv (F. Romagnoli), cabulis@edi.lv (U. Cabulis).

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of vegetable oil in the world with production of 70.19 million metric tons; the first largest source is soybean with 312.81 million metric tons in 2015/2016. In EU-28, in 2015/2016, the production of rapeseed oilseed came to 22,195,000 tons and 198,000 tons of rapeseed oilseeds were imported. Domestic consumption of rapeseed oil reached 10,050,000 tons, from which 71.1% is for industrial (biodiesel, lubricants, other), 28.4% for food consumption (cooking, frying, as an ingredient), and 0.5% as a feed (USDA, 2017). Rapeseed is a widely cultivated crop also in Latvia. Since 2000, the amount of land devoted to rapeseed cultivation has increased vastly. In 2000, 8400 ha were used for rapeseed cultivation; by 2016 it reached 101,000 ha ha (CSB, 2017) from which 75,100 ha (74.3%) was winter rapeseed and 26,000 ha (34.6%) was summer rapeseed (CSB, 2017). Land used for rapeseed cultivation was 8.3% of the total sown area of agricultural crops (1223.9 thousand ha) in Latvia in 2016 (CSB, 2017). One of the reasons for this rise is rapeseed cultivation was the EU's Sugar policy which began in 2006. As a result of major reforms, two Latvian sugar refineries - the Liepaja Sugar Refinery in western Latvia and the Jelgava Sugar Refinery in central Latvia - were closed in 2007 (Ermsone, 2010). Approximately 14,000 ha were used for sugar beet cultivation in 2000–2006. Another reason for the increase in rapeseed cultivation was increased demand for rapeseed due to increase in biodiesel production.

However, since intensive agricultural practices are used for rapeseed cultivation and there has been an exponential growth of rapeseed production, the sustainability of rapeseed production is questioned due to emissions from biodiesel cultivation and indirect land use change (iLUC). The EU has acknowledged this in its Directive (EU) 2015/1513 (2015), the “iLUC Directive,” which amended Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Now the contribution of biofuels produced from “food” crops (to the 10% renewables in transport target) is capped at 7% (Directive (EU) 2015/1513). However, now biodiesel is the most important biofuel in the EU and, on an energy basis, represents 80.6% percent of the total transport biofuels market in 2014 (Biofuels barometer, 2017).

Also, as mentioned above, food and energy crops are also attractive sources of feedstock for the polymer industry to produce more added value products. The polymer industry is also using first generation feedstock as a potential replacement for petroleum based products. There are already several biobased polyol plants up and running in Europe where different vegetable oils are used as a feedstock for polyol production. Given this situation, sustainability is becoming an important facet to be deeper explored. However, there has been little assessment of sustainability through the use of quantitative tools such as Life Cycle Assessment (LCA). There are few published LCA studies of biobased polyols. There is a need for in-depth research regarding the environmental sustainability of biobased PU materials.

Latvian State Institute of Wood Chemistry have developed polyols based on rapeseed oil and have developed biobased, spray applied and 100% volatile organic compounds-free PU coatings (Fridrihsone-Girone et al., 2016). This paper is the first in a series of papers (Fig. 1) that will result in a complete LCA for these develop PU coatings based on rapeseed oil polyols.

According to the LCA methodology developing the Life Cycle Inventory (LCI) part is the most difficult and time-consuming aspect of the whole study. In fact, LCI is a key aspect dealing with the quantification, definition and gathering of a specific in- and out-data set. In this case a process-based LCI method has been selected in order to create a specific inventory for the analyzed system within the considered regions. At the LCI stage the scientific hypothesis it is essentially lying on the novel inventory created within the research work.

This study aims to define a LCI for both winter and spring rapeseed production using primary data sources that are actual agricultural practices used in Latvia as Northern European country. This paper will expand knowledge concerning rapeseed production with respect to regionalized LCI studies. Data were collected from a large crop company in Latvia to ensure a specific and accurate data collection for the definition of the complete supply chain.

2. Methods

The study is carried out according to the ISO Standard 14040 (2006) and ISO Standard 14044 (2006).

2.1. Goal and scope definition

The goal of this study is to carry out a cradle-to-gate LCI of rapeseed (both spring and winter) production in Latvia, to be further involved in a cradle-to-grave LCA for biobased PU using polyol from rapeseed. The starting point is cradle-to-gate perspective – from raw materials production to seed harvesting. The inventory has been carried out to identify and quantify the inputs and outputs associated with the production of oilseed rape in the Zemgale region of Latvia.

2.2. Functional unit

The functional unit (FU) for this study was set as 1 ton of rapeseed. The reference flow selected for this study was 1 ha. It should considered that on average, 1 ha produces 3.5 tons of winter rapeseed and 2.5 tons of spring rapeseed.

2.3. System boundary

The system boundary of oilseed rape production is presented in Fig. 1. Rapeseed cultivation includes soil preparation, fertilization, sowing, weed control and harvesting. The system boundary of the LCI study was chosen in order to show comprehensively inputs and outputs for rapeseed cultivation unit process and to avoid black box unit processes and provide transparent, reproducible results. The selection of the foreground system was based on cut-off criteria approach in fact excluding unit processes contributing less than 1% of the whole life cycle. The product system represented in Fig. 1 is based on actual agricultural practices in the region of the study.

2.3.1. Geographical boundaries

Oilseed rape is grown in the Zemgale region in a cereal and oil seeds production company. The Zemgale region is located in the central part of Latvia and in the central part of the Zemgale plain (Fig. 2). Zemgale has very high proportion of arable land and the most fertile agriculture land of Latvia (Melece and Lakovskis, 2014); it also has a developed agriculture and agricultural processing industry. Zemgale is known as Latvia's granary (SIF, 2017).

All of the components needed for rapeseed production are produced outside Latvia and are imported.

2.3.2. Time horizon

The goal of this study was to use as recent data as possible. Data on the rapeseed growing/production are from actual numbers from 2008 to 2016.

Data about spring oilseed rape production is from 2008 to 2014. For winter rapeseed, the data is from time period 2008–2016.

2.3.3. Data requirements

The goal has been to be as accurate as possible and avoid assumptions as much as possible. The LCI data for the foreground