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ScienceDirect

Energy Procedia 136 (2017) 308–315

Energy Procedia

www.elsevier.com/locate/procedia

4th International Conference on Energy and Environment Research, ICEER 2017, 17-20 July 2017, Porto, Portugal

Acidity reduction in animal fats by enzymatic esterification: economic and environmental analysis

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Abstract

This study examines the economic potential of reducing animal fats acidity by enzymatic esterification and evaluates the carbon and water footprints. Two enzymes scenarios were considered based on experimental data. Results show that operational costs are larger than income generated. To be economic viable, the maximum enzyme cost to process fish oil and mammalian fat should be respectively 9.75 €/kg and 1.0 €/kg. Alternatively, for the fish oil acidity reduction to be cost-effective, its sales price should be increased about 3 %. This new process carbon footprint is 602 ton CO_2-eq/year and the water footprint is 261073 m^3 water/year.

Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.

Keywords: Acidity reduction; Carbon footprint; Economic analysis; Enzymatic esterification; Free fatty acids; FFA; Water footprint

1. Introduction

The consumption of animal products, in particular meat, has increased sharply in recent decades, mainly due to the increase in world population and living standards in developing countries. This state of affairs resulted in a significant increase in by-products from the animal processing sector. In fact, the agro-food industry generates considerable amounts of by-products with no apparent commercial value throughout its value chain. These compounds can be skin,

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1876-6102
Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.
10.1016/j.egypro.2017.10.258

blood, bones, meat trimmings, fat, internal organs, among others animal's by-products originated from slaughterhouses, butchers and supermarkets. Annually North America rendering industry recycles about 27 million metric tonnes of inedible animal by-products [1]. In the same period of time the European Union produces 18 million metric tonnes of that animal by-products [2]. The final disposal of these by-products cannot be done indiscriminately, and their adequate management may lead to potential significant costs for the producer. To reduce the economic and environmental impact, the valorisation of these by-products is a good option, contributing for a more efficient resources use and a circular economy. For example, residual animal fats may be processed to allow their use as a raw material in other industry, such as for animal feed, fertilizer and/or biodiesel [3]. In addition to economic benefits, this kind of solutions promotes environmental and economic sustainability [4]. There are different solutions like composting, anaerobic digestion, incineration, landfills, among others. Nevertheless, it is very difficult, risky to the environmental or too costly.

One of the most interesting alternatives is the rendering industry. In this way these fatty by-products are transformed as raw-material to be utilized as valuable pet or livestock feed ingredients or biodiesel. Rendering is the most efficient and environmentally sound disposal alternative and has a low carbon footprint [1]. However, there are some technical and economic difficulties that are still necessary to overcome. One of them is the high acidity of animal fats that reduces the quality and thus, their commercial value and potential applications. The high acidity occurs, particularly during the summer months when it is exposed to high temperatures during handling and transportation. To reduce the acidity and increase their commercial value various options are available, being the enzymatic esterification one of the most interesting [5,6]. It can be applied to fats from various sources, such as mammalian, poultry or fish oil, and has several important advantages when compared to chemical processes. It is not necessary to use strong acids or alkalis, the operating conditions are milder, and less hazardous reagents, such as ethanol, can be used, while generating water as by-product [7-9]. Hence, this work evaluates the economic viability and the carbon and water footprint of an esterification process for acidity reduction in animal fats (fish oil and poultry and mammalian's fats). The carbon and water footprint were considered in order to estimate the environmental impact of the company's activities. This study considers the application of this process at industrial scale, as a final product treatment after the rendering process. The enzymes considered in the analysis were studied experimentally in this work and the costs and revenues values and environmental information was obtained from the Portuguese rendering company.

2. Methods

2.1. Enzymatic esterification

The use of enzymes as catalysts has been the subject of many studies [5-14] and it is being extensively used in the chemical and biotechnology industries. These biological catalysts are very versatile and allow to operate the processes under milder conditions of temperature and pressure when compared with the equivalent chemical routes. In the case analyzed in this paper water levels in the fat residues are normally low (< 1 %). The presence of water in the residual fat increases the acidity levels and can complicate the action of enzymes and especially the application of other reaction routes such as the inorganic homogenous catalysts. Unlike the chemical process, the enzymatic esterification does not use strong acids or alkalis as homogenous catalysts, operates at low temperatures (< 60 ºC), and can use ethanol as reagent instead of methanol, reducing the human and environmental toxicity of the process [14].

2.2. Economic analysis

The purpose of the economic analysis is to identify the cost and income's sources resulting from the project implementation and operation, and to analyze the cash flows (CF) in order to evaluate the project viability. The revenues result from the sales of products generated in the project. The costs are the expenses required for both the process equipment acquisition and during its operation. The economic viability is assessed using indicators, in particular: the net income (NI), the payback period (PBP), the net present value (NPV) and the internal rate of return (IRR).