BYPROVAL CORNET Project Successfully Concluded

Energy and Cosmetic Ingredients from Vegetable Residues

In the meanwhile completed BYPROVAL research project, PFI Biotechnology and the Belgian research institute Celabor together investigated the extraction of valuable ingredients from selected residues from fruit and vegetable cultivation. The main focus was on residues from pea processing (stalks, leaves, pods), apple pomace, and carrots, which are rich in valuable secondary plant substances. The goal was to generate additional income for existing biogas plants by a combination of extraction and biogas production.

Large quantities of residues from the fruit and vegetable industry are disposed of every year in Germany as animal feed, fertiliser, or as substrate for biogas plants. However, many of these plant residues contain valuable ingredients whose extraction and separate marketing in the cosmetics and pharmaceutical industry would appear very promising. In the BYPROVAL project the residues from pea processing (stalks, leaves, and pods), apple pomace, and carrots were selected on the basis of various assessment criteria from among numerous other potential candidates for further investigation. They contain valuable ingredients with health-promoting properties. These substances should be extracted for marketing prior to energetic utilisation of the biomass in a biogas plant.

Extraction Before or After Silaging?

A preliminary investigation was undertaken to establish the best extraction strategy: before or after preservation by silaging? Silaging is regarded as a standard method for preserving substrates in the biogas sector. On compaction in a silage clamp and exclusion of oxygen, naturally occurring organisms lead to fermentation processes which acidify the material and thus preserve it, as in the case of sauerkraut production.

It could be shown that all three substrates can be silaged. Fig. 1 shows the ranges of acidification after silaging. The dominance of lactic acid fermentation is clearly seen in the case of pea residues and carrots. In contrast, alcoholic fermentation predominates in the case of apple pomace.

All three substrates give satisfactory results with regard to preservation. A more nuanced picture emerges with regard to the extraction process and the substrate-specific target substances. Thus silaging of carrots led to pronounced degradation of the most important target substances lutein and βcarotene (about 90 percent). It is therefore absolutely essential that extraction of the plant contents from this biomass fraction precedes possible silaging.

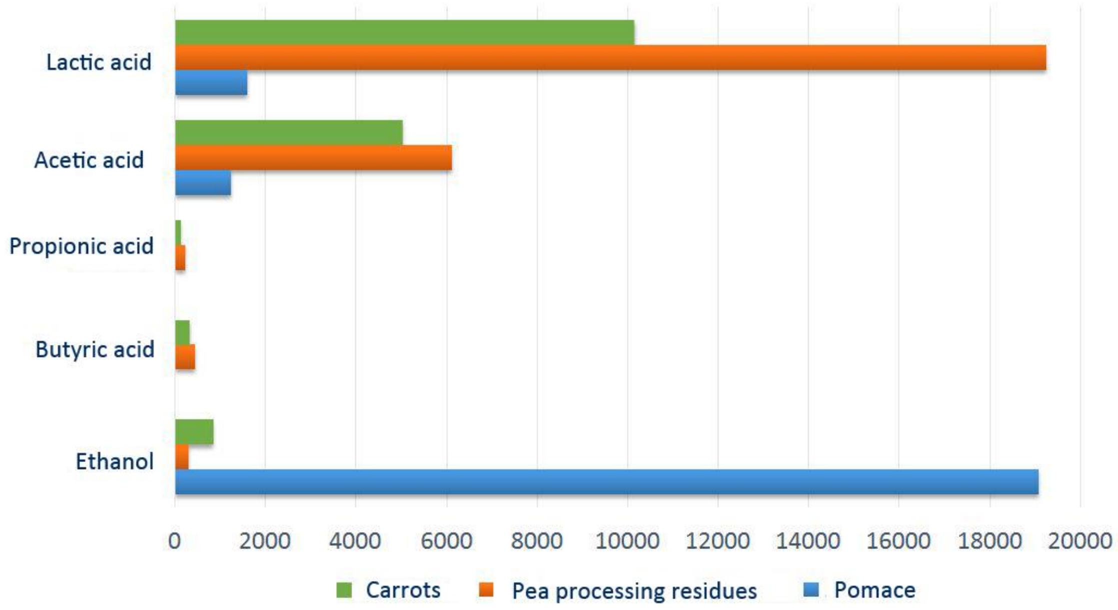

Fig. 1: Acid and alcohol patterns of the substrates after silaging. Concentrations in mg/kg

Especially interesting aspects concerning the effect of silaging on specific target compounds were found for pea residues. This biomass fraction was examined for certain phenolic compounds. The flavanol quercetin was of particular interest owing to its applications in cosmetics and pharmaceuticals. Although a certain degree of degradation of target compounds was found, this was far less pronounced than for carrots. Loss of a sugar unit was found to transform quercetin glycoside into quercetin. Thus silaging had an overall positive effect on specific target substances in this case because the non-glycosidic flavones typically show significantly higher antioxidative activities than the corresponding glycosides.

Biogas Potential of Residues

With a view to the intended combined material and energetic utilisation of the residue fractions, a comprehensive series of experiments was conducted in parallel with the extraction experiments to establish the biogas potential of the feed materials. In addition to numerous static fermentation tests on various fractions, particular attention centred on a long-term test with pea residues after prior extraction. As part of a continuous fermentation test lasting several months, the extraction residues were tested in a co-fermentation set-up with maize. The goal was to determine the expected biogas yields under real-world conditions and to examine the process stability. Fermentation of maize was performed in parallel for reference purposes. The results of the long-term experiment provided unequivocal proof of the suitability of the residues as co-substrate for biogas production. The experimental reactor showed constant gas production and high process stability and the gas yields were only slightly below those of the reference reactor (see Fig. 2).

On the basis of the determined specific biogas yields and the dry matter contents of the extraction residues, it is calculated that about 2.5 tonnes of the material can replace about 1 tonne of maize feed substrate for a biogas plant.

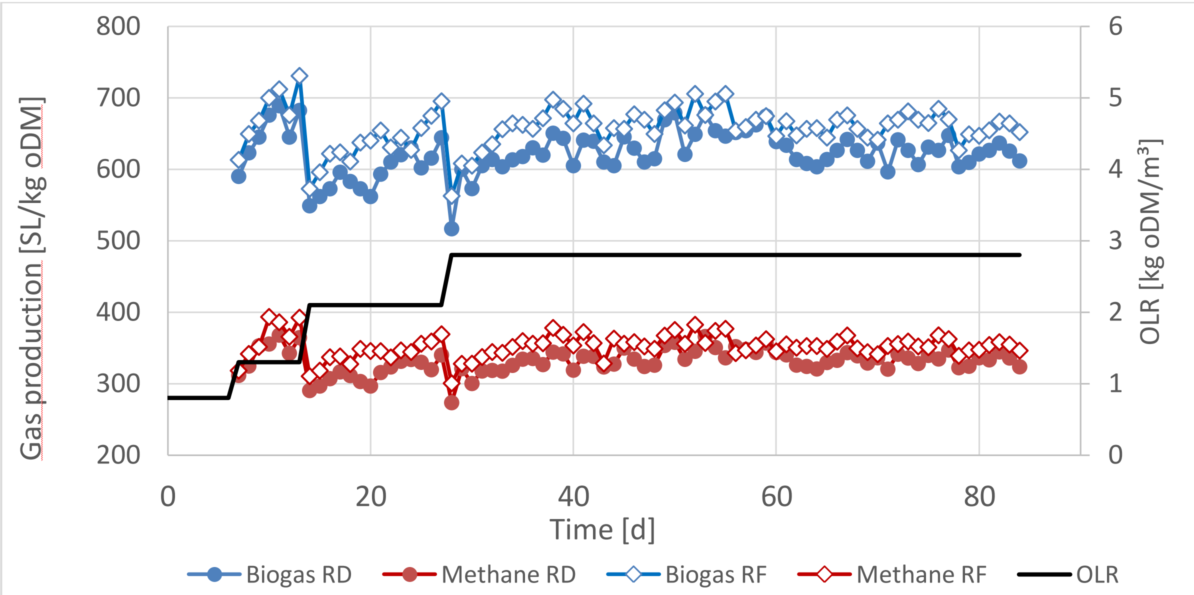

Fig. 2: Specific gas production on co-fermentation of extracted pea residues with maize (reactor RD) compared to monofermentation with maize (reactor RF)

Upscaling the Process

In order that the results can be put into practice more quickly, upscaling of the extraction process from the laboratory to an industrial scale was undertaken as part of the project. On this basis a technological concept was developed for implementation of an extraction unit serving a real-life biogas plant. Specific biogas locations in Germany and Belgium were considered in a case study taking account of the existing infrastructures.

With the set goal of developing and optimising the extraction process, the project partner Celabor had developed a laboratory-scale ASE method (*Accelerated Solvent Extraction*) without use of toxic organic solvents. Evaluation of the methodology indicated a high extraction efficiency in comparison with conventional approaches using organic solvents. The process could be successfully scaled up to industrial proportions at PFI (see Fig. 3).

Fig. 3: Pilot extraction unit in the PFI engineering laboratory. 1 = feed tank; 2 = extraction reactor; 3 = receiver; 4 = steam generator

Based on the results obtained under near real-life conditions and the general technical parameters, a technology concept was prepared for implementation of the process as well as a preliminary economic evaluation. The data obtained in the case studies for locations in Germany and Belgium were also considered, as were the existing infrastructure at the biogas plants and the available thermal energy.

The technological concept was developed for pea residues as biomass fraction and quercetin as target product. The overall process was viewed with consideration of realistically available amounts of the starting substrate. Attention was also given to further processing of the target product all the way to the dried crude extract, including the necessary equipment and the water recovery process.

Subsequent economic evaluation considering the estimated investment, energy, and operating costs put the specific cost for quercetin extracts in a range between 6 and 18 €/kg. The relatively wide range results from the varying amounts of extract produced, which depend largely upon the quality and storage conditions of the starting material, and from the differing technical and infrastructural conditions at the locations considered.

Current market prices for quercetin extracts with comparable contents of active ingredient (10 to 40 €/kg depending upon origin, quality, and quantity supplied) suggest good medium-term prospects for practical implementation of the technology.

Company representatives from the project-accompanying committees of both countries have already indicated their interest in further development of the process. In cooperation with the interested companies, the research partners PFI and Celabor are currently examining the possibilities of further development and timely practical implementation. The IraSME network would offer a suitable platform for such international cooperation between SMEs and industry-related research organisations. Like the Cornet Programme, this international variant of the successful German ZIM Programme is funded by the German Federal Ministry of Economic Affairs with organizational input from the German Federation of Industrial Research Associations (AiF).

This project was conducted in cooperation with the Belgian Celabor Research Institute. Celabor, based in the Walloon Region of Belgium, is an internationally active research institute. It offers scientific and technical support for companies in the agri-food, environmental, packaging, paper, and textiles sectors.

IGF Project No. 152 EN of the Test and Research Institute Pirmasens was funded by the German Federal Ministry of Economics and Energy through the German Federation of Industrial Research Associations (AiF) within the IGF Programme for promoting industrial cooperative research and development in accord with a resolution passed by the German Federal Parliament. We would like to take this opportunity to express our thanks for this funding.

Further information:

Dr. Stefan Dröge
Tel.: +49 6331 2490 846
E-Mail: stefan.droege@pfi-biotechnology.de

BYPROVAL Project

Title: « New Valorization Pathway for Fruit / Vegetable Waste by a Combination of Extraction and Biogas Production»

Duration: 1 January, 2016 – 31 December, 2017

Project partner:

celabor

Funding bodies:

cornet

AiF Forschungsnetzwerk Mittelstand

Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

Wallonie

SPW Service public de Wallonie