

Concentration of pectin water solution using forward osmosis technique - fouling analysis and process optimisation.

In the production of fruit and vegetable juices, besides wastewater, large amounts of solid waste (pomace) are generated, which usually accounts for 10-35% of the processed raw material. These so-called waste pomace due to the content of many valuable natural ingredients, such as pectin, cellulose and hemicellulose, organic acids, vitamins, aldehydes, alcohols as well as coloured and aromatic substances, is used as a feed or is subjected to further processing. The pomace residue from apple juice production is a particularly valuable source of pectin. The apple pulp contains 10-15% pectin on a dry basis, whereas citrus peels up to 20-30%. Currently, the global pectin market is around 80 000 tons per year and still reveals a growing tendency. It should be stressed, that in Poland the issues of production and processing of fruit pomace have huge importance because Poland is the largest apple producer in the European Union and the third in the world (after China and the USA). Pectin is one of the most extensively studied natural biodegradable polymers. Pectins belong to the group of heterogeneous polysaccharides with heterogeneous structure. They are widely used in the food industry as hydrocolloidal additives with gelling, thickening and stabilizing properties. Pectin (designated in the European Union as E440) was classified by the WHO/FAO Expert Committee as a food additive, without limiting the level of its consumption. It is worth noting, that pectins are widely used not only in food (recently as a fat replacement and a healthy functional ingredient) but also in cosmetics and pharmaceutical products as well as in biomedical applications (including drug delivery, tissue engineering and wound healing). However, it should be remembered that each application of pectins begins with the process of their isolation from plant material. Pectin production was started in Germany at the beginning of the 20th century. One of the most energy-demanding stages of the technology is a vacuum concentration which could be displaced by membrane techniques. Unfortunately, attempts of concentrating pectin solution using ultrafiltration were unsuccessful due to the occurrence of fouling which is considered a major drawback of the concentration and purification using selective membranes. The fouling phenomenon reduces the membrane permeability and may eventually cause a complete blockage of the flow. However, there is hope in using a forward osmosis technique (FO) which is driven by the difference of osmotic pressures of solutions separated by a semi-permeable membrane. Such a method is much less susceptible to the deposition of pectin particles on a membrane surface. Furthermore, FO belongs to the group of innovative osmotically-driven membrane separation methods, one of the most promising technologies in the development of the green future of the Earth. Therefore, the general aim of this project is to find the answer to the following question:

Is it possible to effectively concentrate actual aqueous pectin solution using forward osmosis technique?

One of the objectives of the proposed project is to perform a multidimensional analysis of the influence of process parameter on aqueous pectin solution concentration using FO. The experiments will be conducted following the design of experiment methodology. Such an approach allows for the investigation of both main effects and interaction effects of parameters on the effectiveness of concentration. Moreover, the involvement of advanced mathematical apparatus (i.e. principal component analysis) will provide a complex analysis of process parameters.

Despite the lack of hydraulic pressure, a thin layer of pectin particles deposit on a membrane surface. There is a necessity to carry out a comprehensive analysis of the membrane fouling phenomenon occurring during the concentration of aqueous pectin solution as well as the development of an effective method for removing membrane blockage.

The innovative nature of the project lies in using FO to concentrate the solution of the substance which is treated as a membrane foulant. Pectin has never been the main product of concentration using membrane techniques. The investigator will conduct a detailed analysis of the fouling phenomenon using not only well-known methods (SEM, AFM, SFE) but also digital holographic microscopy (DHM) which is a non-disturbing, non-invasive imaging method. Moreover, the blocking layer generation will be modelled in order to determine its mechanism. Common techniques (i.e. resistance-in-series, flux decline and Hermia's model) will be complemented by the autoregressive integrated moving average model (ARIMA) which could be used to forecast water flux behaviour.

Another important aspect of the project will be the optimisation of aqueous pectin solution concentration by FO on the basis of previously determined empirical models. The best operating conditions will be determined using the response surface method (RSM), the desirability function method or evolutionary algorithms. The application of multi-objective optimization methods will improve the efficiency and operating time of concentration which will increase the attractiveness of FO.

This project is an example of combining detailed empirical investigation with a high-level mathematical apparatus. Such an approach leads to propose an interdisciplinary solution to the problem which cannot be solved using only one of these ways. It is the only manner to accelerate the development of science.