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Native protein recovery from potato fruit juice by ultrafiltration

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Abstract

Potato fruit juice, i.e. the stream resulting after the extraction of the starch from the potato, contains up to 2.5% [w/w] of proteins that are potentially valuable for the food market. However, today the recovery of protein from the potato fruit juice with reverse osmosis membranes results in a protein concentrate that is not suitable for human consumption. The described research shows that the use of ultrafiltration with additional diafiltration is able to produce a higher quality protein. Tests with the produced protein show that the quality depends on the rate of diafiltration used and that the product has functional properties that are equal or better than the compared commercial food product that are currently used.

Keywords: Potato fruit-juice; Ultrafiltration; Diafiltration; Protein functionality; Food

1. Introduction

Annually, within the European Union over 2 million tons of fruit juice from the potato starch production is generated. This stream consists mainly of water with a high concentration of potassium and has a high COD (minimally 20,000 mgO_2/l) due to the presence of, among others, proteins, amino acids and sugars. Traditionally this stream is used as fertilizer, but due to low biological activity of the soil during the winter, the juice can not be spread on the fields during a large part of the potato campaign, which takes place from August to February.

In addition to this, in the near future, environ-

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mental regulations might demand an alternative treatment of this stream within the EU.

As the regulations are already compulsory in Germany and The Netherlands since the seventies, the high costs of the wastewater treatment of this stream resulted in several investigations to recover valuable organic substances from this side stream. The research was mostly focussed on the recovery of protein [1–4] by ultrafiltration and reverse osmosis membranes. Today, most of the large starch factories in The Netherlands and Germany have a protein production system installed in order to regain some of the costs involved for treatment. The process involved is a pre-concentration of the stream by reverse osmosis membranes, subsequent heat-coagulation of the protein followed by a separation and drying step. The quality of the protein is low as it has salty, bitter taste and low functionality to make it useful as a food-additive. It is therefore only used as an additive in cattle feed. However, to be an economically viable process the protein should have a high commercial value. Therefore, a research project was started to investigate the possibilities of using membrane processes to produce a high quality protein with good functional properties for human consumption.

2. Experimental

Potato fruit juice is a side stream from the potato starch extraction process and contains everything of the potato except the starch and fiber with the specifications shown in Table 1.

The proteins in this stream, with an average molecular weight of about 50 kD, are in their native form. However, as the proteins are very sensitive towards heat and shear they easily denature during filtration and even during storage. This complicates the membrane process as the desired functional properties are decreasing with denaturation grade. Nevertheless, during the experiments it could not be avoided to produce proteins with different age and therefore quality.

Regarding the experimental procedure, it was found that a pre-treatment of the potato fruit juice prior to filtration was necessary in order to reduce the amount of fibers and especially air, as the juice contains up to 10% (v/v) of air, which causes extreme foaming during the filtration process. For the pilot tests an additional pre-treatment step, flocculation, was tested to remove coagulated protein from the feed.

Table 1
Potato and fruit juice composition in weight percentages

	Potato	Fruit juice (Westfalia process)
Water	75–80	94
Starch	15–20	<0.5
Fibers	1.5	0
Proteins	1.5	1.8
Amino-acids	1.5	1.8
Sugars/salts/acids	2	2.5

3. Results

For the lab experiments pre-treated potato fruit juice was filtered with different UF membranes. Three membrane materials — hydrophilised polyethersulfon, hydrophilised polyvinylidenefluoride and regenerated cellulose with molecular weight cut-offs of 5 to 150 kD — were used. From these tests it was concluded that both pore size and membrane material have little influence on the retention of the potato proteins. This was probably due to the fact that protein concentration was so high that in all cases the filtration setup was operated above the critical flux. It is assumed that as a result a cake layer was formed on top of the membrane that carried out the actual separation process. This could explain why in all cases the amount of protein that was recovered was about the same.

Pilot tests were carried out with commercial plate and frame, spiral-wound and tubular modules. In all cases diafiltration with tap water was carried out in order to wash out low molecular substances like amino-acids, phenolic components, glycoalkaloids and especially potassium. An example

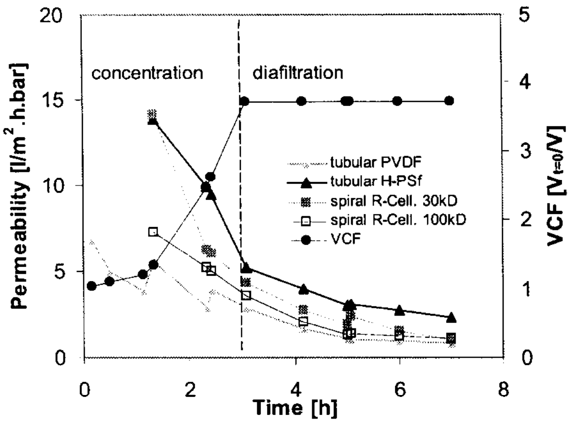

Fig. 1. Batch concentration of potato fruit juice and subsequent diafiltration. The permeability as function of time and volumetric concentration (VCF) factor is plotted.

of the obtained fluxes vs. time and volumetric concentration factor are given in Fig. 1.

Afterwards the protein was spraydried in order to get a stable and dry product that could be transported and stored during longer periods.

The products obtained by the experiments as shown in Table 3 were tested on applicability for the food market. It can be concluded that the chemical composition of produced potato protein concentrates is high enough to be allowed for food applications. This contrary to the traditional product that shows a glycoalkaloid content and salt level that is too high for food-applications.

The protein concentrates were also tested on different functional properties like emulsifying capacity, foam capacity, heat stability and organoleptic properties. They were compared with several other commercial products: egg white, sodium caseinate, whey isolate and soy isolate. It was concluded that both the emulsifying and foam capacity were very good and comparable or better than the best commercial products for these tests; soy isolate and egg white protein. With respect to the heat stability it was concluded that the potato protein foam has a heat stability that was comparable or better than that of egg white foam, which was also the best tested commercial product. However, with respect to gel-stability and water holding capacity the potato protein showed bad results, sodium caseinate, egg white protein and whey isolate all showed better results.

Taste panel tests for the organoleptic properties of the pure potato protein produced by the above ultrafiltration method showed that both taste and smell have been improved substantially compared with the traditional heat coagulation method. Whereas the traditional method of concentrating

Table 2
Water and potato fruit juice fluxes (lab and pilot) of the tested membranes

Membrane	Size	Clean water flux, $l/(m^2.h.bar)$	Potato fruit juice flux, $l/(m^2.h.bar)$
5kD regenerated cellulose	lab	20	3.3
10kD regenerated cellulose	lab	25	20
30kD regenerated cellulose	lab	250	60
30kD regenerated cellulose	pilot	250	25
100kD regenerated cellulose	lab	350	100[1]
100kD regenerated cellulose	pilot	370	15
20kD H-PES	pilot	45	10[2]
20kD H-PES	lab	150	25[1]
30kD H-PES	lab	100	30[1]
50kD H-PES	lab	200	25[1]
100kD H-PES	lab	200	15[1]

All experiments were carried out at 20°C with fruit juice from Emsland Stärke (Westfalia process). [1]Tested with 3 days old juice; [2]Tested with fruit juice from Andels-kartoffelmelsfabrikken Sønderjylland (Larsson process), others with fresh juice.

Table 3
Overview of the conditions and results of the last filtration experiments

Conditions	Lab test	Pilot (1)	Pilot (2)	Pilot (3)	Pilot (4)
Membrane configuration	Plate/lab	Spiral	Tubular	Tubular	Tubular
Flocculation	No	No	No	No	Yes
Filtration time, h	1.5	1	3	3	>7
Filtration temperature, °C	20–30	20	20	20	20
Diafiltration time, h	1.5	—	4	6	>7
Concentration factor during diafiltration	5–10	—	3.5	3.0	10
Water use (% of potato fruit juice)	30	—	50	70	30–50
Quality after Spraydrying					
Humidity, %w/w	5	8	10	8	9
Protein, %w/w	80	82	83	82	82
Ash,% w/w	3.3	7.9	1.9	2.1	3.6
Conductivity, mS/cm	4.3	unknown	1.3	1.7	5.8
% soluble in demi-water	80	63	37	40	53

the potato protein gives a product with unacceptable bitter and roasty taste with a high salt level and strong off-smell, the new product smells and tastes only faintly after raw potatoes. As it is unlikely that the protein will be used in food-products in a concentration higher than 10% (%TS) both taste and smell could be masked by other flavor components. Tests with meat products where the commercial protein additives were replaced by potato protein confirmed this.

When the different potato protein products are compared to each other it is found that both the functional properties and the organoleptic properties of the products which were washed out via diafiltration showed the best results, with more diafiltration giving a better protein quality in that respect.

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