Purification and concentration of potato juice by ultrafiltration and nanofiltration

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Abstract. In this article are proposed and investigated the baromembrane methods for purification of potato juice with recycling. The resulting concentrate could be used as a feed and food additive. The optimal technological parameters of the ultrafiltration stage – the type of membranes, the molecular weight cutoff, the process temperature, and the operating pressure are analyzed and determined.

1. Introduction
Potato juice (PJ) is a by-product obtained in the manufacture of potato starch. PJ is a complex mixture with content of dry matter (DM) up to 6% (mass). At the same time, 20-27% of DM made up of proteins that are valuable for the food market. DM consists of glycoalcoloids, free amino acids, sugars, lipids, organic acids, phenolic compounds, minerals, and other components [1-2]. figure 1 shows the potato starch production scheme.

The approximate composition of PJ is presented in table 1. The concentration of phenolic compounds and glycoalkaloids is of particular interest, because their presence can cause problems with the usage of potato protein as a food additive. Potato proteins can be divided into 3 main groups: patatins, protease inhibitors and various enzymes. Their concentration depending on the potato cultivar.

Patatin presents in the tubers, mainly in the form of a dimer. It is a glycoprotein, containing neutral sugars, hexosamine and amino acids. It is characterized by a molecular weight of 45 kDa, isoelectric point of patatin is of pH = 4.5-5.1.

The second group of proteins includes protease inhibitors with a molecular weight 5 - 25 kDa and isoelectric point pH = 5.0-8.0. It is believed that they are reserve proteins, sources of sulfur-containing amino acids [3-4].

The other proteins are lectins, polyphenol oxidases, lipoxygenases, enzymes involved in the synthesis of starch and phosphorylase isozymes with a molecular weight above 40 kDa.
Figure 1. Stages of potato starch production.

Table 1. Average composition of potato juice [5].

| Component                                | % (mass) of dry matter |
|------------------------------------------|------------------------|
| Protein (N × 6.25)                       | 26.8                   |
| Peptides (N × 6.25)                      | 4.4                    |
| Amino acids and amides (N × 5.13)        | 9.6                    |
| Other N-containing compounds             | 1.8                    |
| Sugars                                   | 15.8                   |
| Lipids                                   | 2.2                    |
| Organic acids                            | 13.2                   |
| Chlorogenic acids                        | 0.4                    |
| Caffeic acids                            | 0.1                    |
| Potassium                                | 11.2                   |
| Phosphorus                               | 1.0                    |
| Other components                         | 13.5                   |

The bulk quantity of PJ is dumped. That adversely affecting on the environment. Most of industrial companies don’t have purification systems or use suboptimal equipment. That doesn’t allow to use the potato protein for further processing. Therefore, the development and implementation of effective methods for PJ purification is an urgent problem.

Heat coagulation and acid precipitation are commercial methods for isolating protein from industrial PJ. The main disadvantage of this process is the necessity of additional operations of decolorization and removal of unpleasant odors of obtained protein.

Membrane technology allow to process of protein suitable for usage as food and feed additives. At the same time, it will reduce the total cost of water, by reusing it after cleaning potato juice.

There are only a few publications describing reverse osmosis, ultrafiltration (UF) and nanofiltration (NF) as methods for purification and concentration potato juice [5-10]. However, there is no full-
fledged research, so the study and development of purification systems based on membrane methods is prospective.

2. Materials and methods
Objects of the study were native PJ with concentration of dry matter 4.2% (mass) and heat-treated PJ with DM concentration 3.7% (mass). Thermal treatment reduces the fiber concentration in PJ. Temperature of processing was in range of 90-100 °C during 5-10 minutes.

The analysis of UF efficiency was carried out on a laboratory installation working in dead-end and tangential filtration regimes. The laboratory plant consists of 5 modules with hollow fiber membranes, characterized by molecular weight cutoff 10; 30; 50; 100; 150 kDa. The membranes materials are polysulfone and polyethersulfone. The experiments were carried out in the maximum concentration mode. The flow sheet of experimental plant is shown in figure 2.

The NF process was studied in the pilot plant consisting of nanofiltration spiral-wound membrane module, pressure boosting pumps, measuring and recording apparatus and tanks.

![Flow sheet of ultrafiltration experimental plant.](image)

3. Results
The main part of PJ is water, which after purification can be reused in technological cycle. That's why at the beginning it is necessary to detecting the maximum concentration degree of PJ proteins. The experiments were carried out on UF plant (Figure 2). Permeate after membrane module was removed to the initial tank. The temperature of the native PJ was 20 °C to prevent possible protein denaturation. The operating pressure difference was of 3 bar. Temperature, pressure drop, and specific capacity monitored using a contact thermometer, pressure gauge, and rotameter.

The dependences of membranes flow rate versus the experiment time are presented by figure 3.

Based on the obtained data, it can be concluded that with a decrease in membrane molecular weight cutoff, it's flow rate increases, as well as the constant value in steady-state conditions.
Figure 3. Membranes flow rate during the experiments.

Table 2. DM concentration in separated media.

| Membranes molecular weight cutoff, kDa | DM in concentrate, % mass | DM in permeate, % mass |
|---------------------------------------|---------------------------|-----------------------|
| 150                                   | 10.9                      | 1.9                   |
| 50                                    | 13.3                      | 1.7                   |
| 30                                    | 15.7                      | 1.7                   |
| 10                                    | 19.1                      | 1.5                   |

Further experiments for water purification were carried out using the UF hollow fiber membrane module characterized by molecular weight cutoff of 50 kDa and on NF spiral-wound unit. Heat-treated PJ was the initial solution. Pretreatment was necessary for reduction of DM amount. Permeate after the UF stage with an average concentration of DM 1.6% was separated on NF stage. The aim of experiments was to determine the influence of the main technological parameters on membranes rejection. Table 3 and 4 show the results of the experiments.

Table 3. Temperature dependence of UF membranes rejection.

| Temperature of PJ, °С | DM in permeate, % mass | Rejection, % |
|-----------------------|------------------------|--------------|
| 20                    | 2.1                    | 43.2         |
| 25                    | 2.0                    | 46           |
| 30                    | 1.9                    | 48.6         |
| 35                    | 1.8                    | 51.3         |
| 40                    | 1.7                    | 54           |
| 45                    | 1.5                    | 59.5         |

Based on the results shown in table 3, it can be concluded that with temperature increasing, membranes rejection rises. This fact could be explained by coagulation of proteins in heated solution.

The driving force augmentation leads to membrane densification and reducing of pore size. That causes the increasing in membrane rejection.

4. Discussion

The value of the membranes flow rate with a change of initial temperature and process driving force slightly in the range of 28-35 l/m²*h. Their decrease flow rate in all experiments cause be explained by
the formation of concentration polarization layer on the surface of the membrane. This layer also increases the membranes rejection.

### Table 4. UF and NF membranes rejection.

| Driving force, bar | DM in permeate, % mass | Rejection, % | DM in permeate, % mass | Rejection, % |
|-------------------|------------------------|-------------|------------------------|-------------|
| 1.5               | 2.2                    | 40.5        | 0.8                    | 50          |
| 2.0               | 1.9                    | 48.6        | 0.8                    | 50          |
| 2.5               | 1.9                    | 48.6        | 0.7                    | 56          |
| 3.0               | 1.9                    | 48.6        | 0.7                    | 56          |
| 3.5               | 1.9                    | 48.6        | 0.3                    | 81.3        |
| 4.0               | 1.6                    | 56.7        | 0.3                    | 81.3        |
| 4.5               | 1.3                    | 65          | 0.2                    | 87.5        |
| 5.0               | 1.3                    | 65          | 0.2                    | 87.5        |

Implementation of two-stage purification system based on ultrafiltration and nanofiltration allow to concentrate PJ (native and heat treated) and obtain purified technological water. The optimal temperature of purified PJ at the ultrafiltration and nanofiltration stage is 45°C, and the driving force must be at least 4.5 bar for achieving the optimal rejection. Using two-stage plant, it was possible to concentrate the dry matter up to 19.1 % mass. That value allows to use the proteins after further processing, both for feed and food purposes. At the same time, concentration DM in permeate decreases by 95% mass. Permeate could be used for technological processes.

### 5. Conclusion

The use of membrane technology in the purification and concentration of potato juice makes it possible to obtain both protein concentrate and purified water. Combination of baromembrane processes renders possible the using of purified proteins not only for feed, but also for food additives production.

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