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# ENERGY-SAVING METHOD FOR OBTAINING PROTEIN FROM POTATO JUICE

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Key words: potato, potato juice, protein, coagulation, ultrafiltration, energy consumption

Protein was isolated from potato juice by acid-thermal coagulation and by ultrafiltration. The purity of the obtained protein preparations and energy consumption in the two methods were compared. It was founed that protein obtained by a concentration of juice by the ultrafiltration method was of higher quality and for its production more than twice less energy was required.

## INTRODUCTION

Potato juice containing considerable quantities of nitrogen compounds, including protein, was considered to be, a burdensome industrial waste. The studies on the treatment of this effluent covered also the problem of recovery of protein which is a valuable product. It was stated that the mere separation of protein substances from juice caused a decrease of the wastes contaminating agents by 30%. The suggested methods for the separation of protein, such as the thermal, acid, acid-thermal and ion exchange- thermal coagulation methods make it possible to isolate quite efficiently protein substances from juice. However the energy outlays in these processes are wery high and economically hardly justified.

In recent years, attention was drawn to a relatively new method of concentrating protein substances by ultrafiltration which is attractive due to law energy consumption [3, 4, 5, 11, 13, 15, 16]. The phenomena and processes connected with ultrafiltration, being known for a long time [17], could be applied in industrial conditions after long and toilsome studies aimed at obtaining reliably working membrane baffles. Such membranes, apart from their selective permeability, should be characterized by mechanical stability, high resistance to chemical agents and temperature and a high resistance to cyclic loadings [1, 9, 14].

Application of new materials [2, 6, 8] allowed to produce more selective membranes of different geometrical shapes, i.e. flat, tubular and capillary [9, 14].

Progress in the production technology of membranes and improvement of their properties led to attempts of a wide application of the ultrafiltration process in various industrial sectors [3, 6, 7, 11, 12, 13]. Also in the potato industry [15, 16] provided that appropriate membranes are selected, the process of ultrafiltration may applied to recover protein from potato juice, at much lower energy costs as compared with methods proposed so-far.

## AIM OF THE STUDY

The aim of this study is to compare the consumption of energy during the process of obtaining protein preparation from potato juice by the classical method, i.e. acid-thermal technique and by the method of membrane concentration.

## EXPERIMENTAL

For the study, a fresh, diluted potato juice from the same batch of potatoes was used. The sample of juice was divided into two parts. From one part protein substances were isolated by the acid-thermal method and from the second — by membrane condensation (ultrafiltration). A flow diagram of the applied methods is shown in Fig. 1.

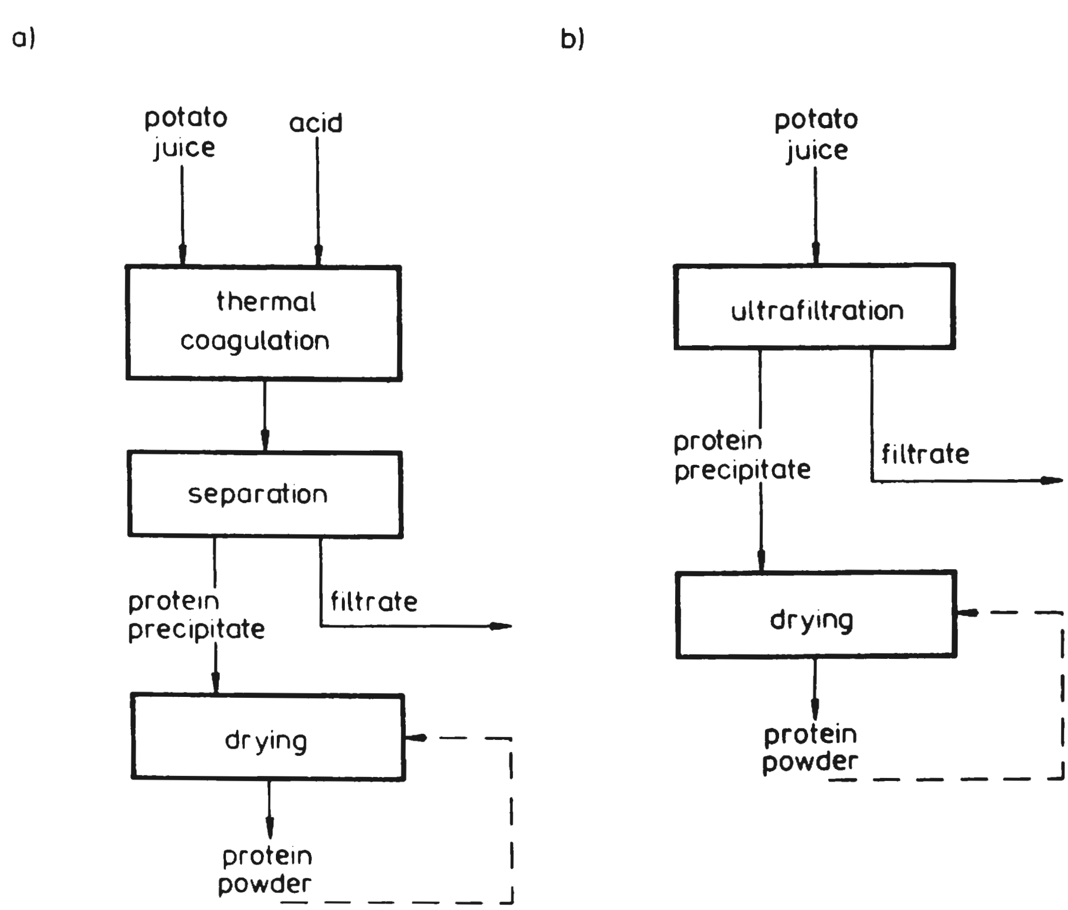


Fig. 1. Flowsheet of the process of obtaining protein substances; a — by the acid-thermal method, b — by the membrane concentration method

In the acid-thermal method, potato juice was acidified with sulphuric acid to a pH optium for protein coagulation (pH = 4) and then it was heated to 85°C. The coagulated protein was separated in a centrifuge. The filtrate was removed (discarded) and the obtained mass of protein (protein precipitate) was dried in a dispersion drier. The process of drying was conducted with a recirculation to the mass of a part of the previously dried preparation. A simpler modification of this method is thermal coagulation alone which gives a somewhat smaller efficiency of protein separation.

In the second method, protein substances were obtained by condensation of juice first on membranes (ultrafiltration) and then, by drying the concentrate in a dispersion drier with recirculation of the dried substance like in the former process.

The ultrafiltration process was conducted with the use of capillary poliacrylonitrylic membranes of an inner diameter equal to 1 mm, arranged in a bundle with a filtration surface of 0.027 $m^2$. The linear flow rate in the capillaries was about 0.6 m/s. Pressure of liquid at the inlet of capillaries was 0.2 MPa and temperature of juice was maintained within 20°C ± 1. The rate of filtration was determined by taking the filtrate every 20 minutes and measuring its volume.

In both methods, potato juice, protein precipitate and filtrate were analysed. In all solutions, the content of dry matter, total nitrogen by Kjeldahl method, amino acid nitrogen by Sörensen method [10] and mineral substances (sulphate ash), were determined.

## RESULTS AND DISCUSSION

In each of the methods samples of 3 kg from the same potato juice were taken for the studies. Keeping all the parameters of both methods described protein preparations and filtrates were obtained. The results of analyses of the initial potato juice, filtrates and protein precipitate before drying, are shown in Tables 1 and 2.

Table 1. Results of the analyses of substrates and products in the acid-thermal method used for obtaining protein

| | Dry substance % | Total nitrogen | | | Amino acid nitrogen | | | Sulphate ash | |
|---|---|---|---|---|---|---|---|---|---|
| | | % | g / 100 g d.m. | g·6.25 | % | g / 100 g d.m. | g·6.25 | % | g |
| Potato juice (3000 g) | 5.4 | 0.40 | 7.4 | 75.00 | 0.116 | 2.1 | 21.75 | 1.53 | 45.9 |
| Filtrate (2500 g) | 4.1 | 0.246 | 6.0 | 38.44 | 0.115 | 2.8 | 18.00 | 1.50 | 37.5 |
| Protein precipitate (500 g) | 11.6 | 1.15 | 9.9 | 35.94 | 0.112 | 1.0 | 3.50 | 1.60 | 8.0 |

Table 2. Results of the analyses of substrates and products in the membrane method used for obtaining protein

| | Dry substance % | Total nitrogen | | | Amino acid nitrogen | | | Sulphate ash | |
|---|---|---|---|---|---|---|---|---|---|
| | | % | g / 100 g d.m. | g·6.25 | % | g / 100 g d.m. | g·6.25 | % | g |
| Potato juice (3000 g) | 5.4 | 0.40 | 7.4 | 75.00 | 0.116 | 2.1 | 21.75 | 1.53 | 45.9 |
| Filtrate (2720 g) | 3.8 | 0.22 | 5.8 | 37.4 | 0.11 | 2.9 | 18.70 | 1.50 | 40.8 |
| Protein precipitate (244 g) | 19.5 | 2.33 | 11.9 | 35.53 | 0.15 | 0.8 | 2.29 | 1.68 | 4.1 |

3 kg of potato juice containing 75 g of nitrogen substances calculated as crude protein, were introduced into the process. About 36 g of crude protein were isolated by the acid-thermal method (Table 1) what constitutes aboud 48% of the introducend nitrogen substances. The residual amount of nitrogen compounds and more than 80% of mineral substances remained in 2.5 kg of filtrate, as a by-product. The quantity of (weight) protein precipitate was 6 times smaller than the amount of potato juice introduced to the process. After drying the protein precipitate about 60 g of dry protein preparatin (protein powder) containing about 60% of nitrogen compounds in d.m. were obtained.

In the ultrafiltration method (Table 2), from the same quantity of juice and total nitrogen introduced with it, the same amount of nitrogen substance was obtained in the protein precipitate but its volume was 2 times smaller than in the acid-thermal method. Moreover, 2720 g of filtrate containing almost 90% of mineral substances and 50% of nitrogen substances introduced with the juice to the process, were obtained. The weight of the obtained protein precipitate amounted to 12% only of the mass of the introduced juice. After drying, the content of nitrogen compounds in protein powder was about 70%.

The energy outlays for membrane condensation of protein substances, at a decreasing rate of filtration, are directly proportional to the duration of this process. From the economical point of view, the average rate of filtration should be not less than 13 $dm^3/m^2$ h because the rate of filtration, measured during the final stage of concentration (below 15% DM) starts to be so small that it becomes technically and economically unjustifiable. The course the ultrafiltration process is presented in Table 3.

Taking into consideration the technological conditions of obtaining the protein preparation by both methods the demand for energy at the particular technological stages was calculated.

The calculations took account of the following parameters:

1) the initial amount of potato juice — 3 kg
2) temperature of juice = 10°C

Table 3. Filtration process for potato juice

| Time of filtration (min) | Filtrate (g) | Σ of filtrate (g) | Rate of filtration $dm^3/m^2h$ | Average rate of filtration $dm^3/m^2h$ |
|---|---|---|---|---|
| 10 | 133 | 133 | 29.6 | |
| 30 | 243 | 376 | 27.0 | |
| 50 | 233 | 609 | 25.9 | |
| 70 | 233 | 842 | 25.9 | 25.5 |
| 90 | 226 | 1068 | 25.1 | |
| 110 | 221 | 1289 | 24.6 | |
| 130 | 196 | 1485 | 21.8 | |
| 150 | 185 | 1670 | 20.6 | |
| 170 | 165 | 1835 | 18.3 | |
| 190 | 152 | 1987 | 16.9 | 15.3 |
| 210 | 124 | 2111 | 13.8 | |
| 230 | 114 | 2225 | 12.7 | |
| 250 | 99 | 2324 | 11.0 | |
| 270 | 94 | 2418 | 10.4 | |
| 290 | 79 | 2497 | 8.8 | |
| 310 | 65 | 2562 | 7.2 | |
| 330 | 50 | 2612 | 5.6 | 6.3 |
| 350 | 42 | 2654 | 4.7 | |
| 370 | 37 | 2691 | 4.1 | |
| 390 | 29 | 2720 | 3.2 | |

Inlet pressure 0.2 MPa
Outlet pressure 0.1 MPa
Flow rate 0.57 m/s

3) specific heat of juice – 4.1 KJ/kg·K

4) temperature od protein coagulation in acid-thermal method = 85°C

5) for separation of coagulation, a separator K-70, with engine power 0.75 kW was used; working capacity of cuvettes 2 $dm^3$, number of revolutions 314 rad/s
time of centrifugation 180 s

6) the pump used in the ultrafiltration process, cooperating with filter of 1 $m^2$ surface, consumed 0.6 kW, ensuring a flow rate of juice 0,57 m/s
average rete of filtration was 15.5 $dm^3/m^2h$

7) consumption of energy in pneumatic drier depends on the quantity of substance recycled, usable difference of temperature, on the content of dry matter in protein precipitate and on the content of water in protein powder. In the studies, it was stated that the whole drying system consumes for the evaporation of 1 kg water — an average amount of energy equal to 2.2 kg steam.

The calculated demand for energy needed to obtain protein powder from 3 kg of juice by the acid-thermal method is as follows:

| | | |
|---|---|---|
| 1) thermal coagulation | | 922.5 kJ |
| 2) centrifugation | | 201.6 kJ |
| 3) drying | | 2173.2 kJ |
| | Total | 3297.3 kJ |

Consumption of energy required to obtain 1 kg of protein powder by the drying of thermal coagulates amounts to 57 MJ and in therms of 1 kg of crude protein obtained by this method it amounts to 91.64 MJ.

The demand for energy needed to obtaining protein powder from 3 kg of potato juice by the membrane method is as follows:

| | | |
|---|---|---|
| 1) process of ultrafiltration | | 379 kJ |
| 2) drying | | 953.7 kJ |
| | Total | 1332.7 kJ |

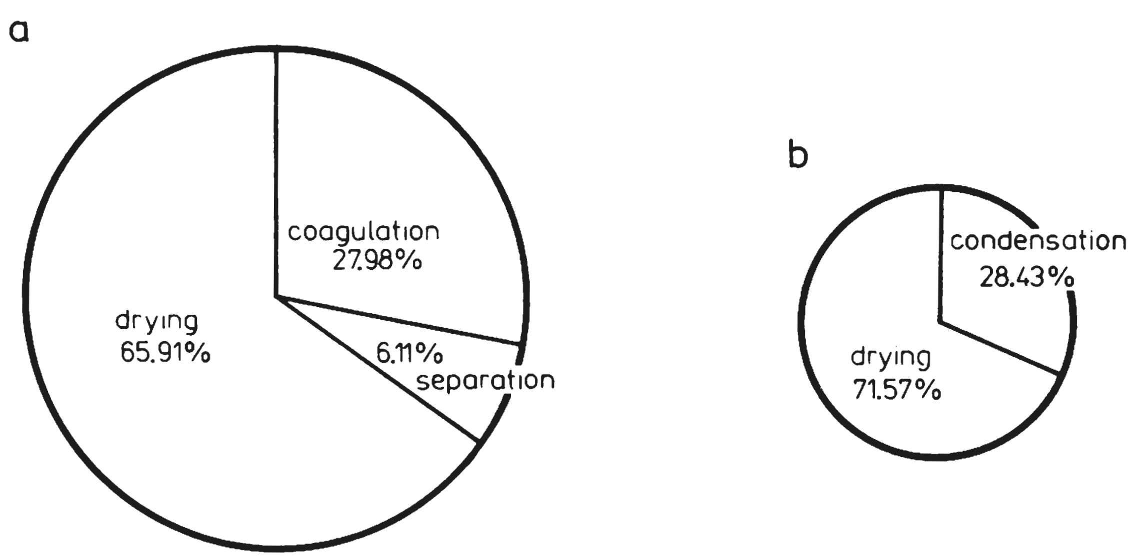


Fig. 2. Amount of energy needed for the separation of 1 kg of crude protein from potato juice, with consideration of the particular stages of the technological process

Hence, the consumption of energy for obtaining 1 kg of protein powder by the method of drying the protein precipitate after ultrafiltration is 28 MJ and calculated into 1 kg of crude protein obtained by this method, it is 37.5 MJ. Fig. 2 presents the percentage share of energy consumption in the particular stages of the technological process.

The results make it possible to state that the amount of energy needed to, obtain protein precipitate with the same concentration by the ultrafiltration method is considerably lower than in case of the acid-thermal method. The mere consumption of energy needed for heating the juice for coagulation of protein is many times higher than energy consumption in the process of membrane concentration. If we assume that it is possible to obtain in both methods an equal concentration of protein percipitate, then the demand for heat used to dry this precipitate will be identical but the total energy costs for the production of 1 kg of dry protein will differ considerably and will be much lower in the membrane method than in the thermal one.

Under industrial conditions, at an optimum selection of devices and equipment, with consideration of energy-saving processes, the energy needed to produce a dry protein preparation by the thermal-acid coagulation method be decreased. e.g. due to the introduction of special sedimentation centrifuge, called protein separators for the preliminary condensation of the coagulant making it possible to concentrate the coagulate to above 20% DM. A condition for the effective application of these separators is coagulation of protein, at 110°C, not 85°C. This improvement has a short-coming: it increases energy consumption for an additional heating of juice and undoubtedly deteriorates the structure and dietetic value of the protein. Nevertheless it is possible to obtain high savings of energy during the process of dryng the protein precipitate and to make the whole process more profitable. Similar thermal improvements of the membrane process create premises for, obtaining equally significant savings in the future. In both methods, a correct course of the technological process requires a rather complicated equipment.

## CONCLUSIONS

1. The method of ultrafiltration makes it possible to replace the energy consuming process of heating in order to coagulate protein contained in large quantities of juice and to isolate the coagulated protein.
2. The amount of energy needed for the separation of protein from juice by the ultrafiltration method is definitely (more than twice) lower than in the so-far applied method of acid-thermal coagulation.
3. In both methods, the greatest consumption of energy occurs during drying of protein precipitate.
4. The ultrafiltration method allows to obtain a protein preparation of a considerably higher quality standard, in comparison with methods based on coagulation of protein (Table 1 and 2).

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## ENERGOOSZCZĘDNA METODA POZYSKIWANIA BIAŁKA Z SOKU ZIEMNIACZANEGO

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Streszczenie

Z soku ziemniaczanego uzyskiwano produkt białkowy metodą kwasowo-termicznej koagulacji oraz metodą membranową z zastosowaniem ultrafiltracji. Udział azotu ogólnego w przeliczeniu na suchą substancję produktu białkowego otrzymanego metodą kwasowo-termiczną wynosił 9,9%, a metodą zatężania membranowego 11,9%. W obu metodach stosowano ten sam sok w ilości 3 $dm^3$ i uzyskano w produkcie białkowym zbliżoną ilość białka surowego tj. po ok. 36 g. Przy założeniu jednakowego stężenia koncentratu białkowego przeznaczonego do suszenia ilości energii zużytej w procesie otrzymania 1kg produktu białkowego w obu metodach znacznie się różniła; w metodzie kwasowo-termicznej wynosiła 91,6 MJ a w metodzie zatężania membranowego 37,5 MJ. Zastosowanie ultrafiltracji do wydzielania białka z soku zamiast koagulacji kwasowo-termicznej pozwoli uniknąć bardzo energochłonnych i trudnych operacji technologicznych za pomocą urządzeń wyłącznie produkcji krajowej.