ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2018, Vol. 07, No. 4, 9 – 12

New data acquisition system for birch sap concentrate production using the reverse osmosis technology

J. Wawer[1], M. Bilek[2], S. Sosnowski[2]

[1] Department of Physical Chemistry, Faculty of Chemistry, Gdańsk University of Technology, Poland
Narutowicza 11/12, PL 80-233 Gdańsk, Poland
e-mail: jarwawer@pg.edu.pl

[2] Department of Food and Agriculture Production Engineering, Faculty of Biology and Agriculture, University of Rzeszów, Poland
Zelwerowicza 4, PL 35-601 Rzeszów, Poland

e-mail: mbilek@ur.edu.pl, ssos@ur.edu.pl

Received October 18.2018: accepted December 20.2018

Abstract. The work presents a simple electronic device that helps to monitor the basic parameters of the reverse osmosis (RO) system during the concentration of birch tree sap. The construction costs are low (around 150 Euro) but the functionality of the device is high. It has an in-build two channel conductometer and can measure the volumetric flow rate of two streams of liquids. The collected data are transmitted wirelessly via Bluetooth to a PC computer. The new data acquisition system can help to monitor the work of RO apparatus in standard conditions or in the research and development works. It provides essential data for the process modeling and economic aspects analysis of birch sap concentrate production.

Keywords: data acquisition, microcontrollers, birch tree sap, reversed osmosis, new technologies

INTRODUCTION

Birch tree sap is not a particularly popular food product but its consumption is constantly growing. For further and even more dynamic sales increase a large number of problems need to be addressed.

First of all, the product must be safe for consumers. The amount of the toxic compounds assimilated from the environment must be minimal. The trees growing in the vicinity of farmlands or roads may be not suitable for the sap collection because the product could be contaminated with pesticides or heavy metals from fertilisers [1,2]. It seems that it would be much safer to collect the sap from trees growing in the woods provided that the region has not been polluted earlier and the history of previous usage of these areas has been well documented [1].

Secondly, the stability of raw sap is low and must be extended. It would be unreasonable to spoil the harvested high-quality product by heat treatment or by artificial food preservatives addition. Several strategies to increase shelf life have been described in literature [3-5] and the awareness of this problem is of utmost importance.

Finally, the birch sap taste is rather bland. This may be considered by a group of consumers as a serious drawback. Some of them may be unsatisfied and not purchase the product again. The concentration of substances in birch sap is relatively low. The content of sugars, mostly fructose and glucose, is around 4-5 g/dm^3 for each [6,7]. The malic acid and amino acids (glutamine, citrulline and glutamic acid) are present in even lower amounts - around and less than 0.5 g/dm^3 [7,8]. Raw sap contains also various inorganic cations and anions [9,10]. These data clearly explain why the birch sap flavour is weak. To overcome this disadvantage and to improve the taste and properties of unprocessed product, birch sap based soft-drinks can be prepared [11]. An interesting option is to produce sap-based, probiotic-fermented beverages [12].

As an alternative to these proposals the natural sap can be concentrated using the reverse osmosis technique (RO). The sugars concentration in the final product can be as high as 13°Brix [13] but, in our opinion, such extensive treatment is neither necessary nor economically sound. It would be more appropriate to stop the process at the point where much more diluted product is obtained (2-4°Brix) [14].

In one of our earlier works we presented the simple reverse osmosis apparatus for the concentration of birch tree sap [14]. So far, we have analysed the sap concentration process from the point of view of the obtained concentrate composition [15] and energy consumption during the concentration [16].

The aim of the present work is to present a modern and inexpensive data acquisition system which will allow to monitor birch sap concentrate production using the reverse osmosis technology. The system can monitor the conductivity of the concentrate and permeate (two-channel conductivity meter) as well as the flow of feed and concentrate (two-channel flowmeter). The collected data are wirelessly transmitted via Bluetooth, then saved and presented in a personal computer.

The device allows to estimate the changes in the product concentration and provides the in-line control of the volumetric flow rate of liquid streams. It helps to optimise the RO process in terms of operation costs and time consumption. It could be easily scaled up for larger semi-industrial applications.

MATERIALS AND METHODS

Birch tree sap was collected as described by Yoon et al. [17]. The trunk was drilled with a drill bit with the diameter of 16 mm and the hole depth was 4-5 cm. The sap from four birch trees (Betula pendula Roth.) was collected in Łukawiec village (50.097559, 22.168178), mixed and then frozen and stored in a freezer.

The sap samples were concentrated using the reverse osmosis apparatus described in our previous works [14, 16], at the working pressure around 2 bar. The RO device was equipped with four sensors. The systems collected four data strings - two for conductivity and two for volume flow. The position of these sensors is presented in Figure 1.

The conductivity sensors were taken from the TDS81 flow conductometer. The electronic part of this device was replaced by the electronic systems that we had built based on the available scheme [18]. To measure the volumetric flow rate the precision flowmeters were used (Digmesa 0.1121 – 0.9068 l/min, Model: 932-9506/B).

The block diagram of data acquisition system is shown in Figure 2.

The system is controlled by the microcontroller ATmega328A. The equivalent of the module Arduino Pro Mini was used [19]. The processor clock frequency was set to 16 MHz. The microcontroller-conductometer interface was implemented as in the scheme [18]. The interface connection between flowmeter and data acquisition system was made in accordance with the datasheet provided by the flowmeter manufacturer (interface version: “Simple circuit”). The presented system was equipped with two voltage stabilizers. The first one is a standard application of the 7805 integrated circuit. This source supplies all the modules which require 5V voltage. The second stabiliser (application of the LF33CV) supplies the logic level converter. The conversion of levels was necessary to establish a safe transmission of data between the microcontroller and Bluetooth module (HC-05). A bi-directional level converter was constructed using BSS138 transistors [20]. The time at which the measurement is made is read from the Real-Time Clock (module with DS1307). The software for the microcontroller was written in Bascom language. The PC software was written in Python (3.4). The source codes are available online [21-23].

The guidelines for the conductometer adjustment and calibration have been described on the website [18]. Shortly, the generator was being adjusted until the oscillations occurred (potentiometer V1), the conductivity was measured at 10 kHz. The range of the readings was set to almost maximum (potentiometer V2). The offset was set to zero (potentiometer V3). The conductivity probes were immersed in the solutions with the highest conductivity. The output level was adjusted (10 kohm potentiometer in the gain loop soldered in the place of the R7 resistor) to around 90% of the maximal readings (4.7V). The probes were removed and dried, the level of the offset was rechecked and set to zero if necessary (potentiometer V3). One standard solution was used at this stage of adjustments for each channel. For the permeate (channel A of conductometer) the solution had the conductivity of 530 uS/cm. For the concentrate (channel B of conductometer) - 2100 uS/cm.

After the hardware adjustments the conductometer was calibrated. Two standard solutions were used for channel A (permeate): 84 uS/cm and 530 uS/cm. Three standard solutions were used for channel B (concentrate): 530 uS/cm, 1345 uS/cm and 2100 uS/cm.

The linear calibration curves “ADC level = f(conductivity)” were plotted in Microsoft Excel and the parameters of the equations were used to convert the ADC readings of the microcontroller to conductivity (Python software lines 387 and 411 of code). To improve the accuracy of the measurements the re-calibration could be performed at the beginning and end of the concentration process with the help of the external conductometer.

To achieve the best accuracy, each of the flowmeters must be calibrated separately. The parameters of the calibration equations were written in the Python software (channel A feed flow line 312, channel B concentrate flow line 351).

RESULTS AND DISCUSSION

The screenshot of the Python application user interface, written for this project, is shown in Figure 3. The points on the presented charts correspond to the measured parameters during the concentration process of raw birch sap. The small disturbance observed on the plot of concentrate conductivity was probably caused by an air bubble (which is not uncommon in the reverse osmosis process).

The data from the conductometer and flowmeters were collected every minute and plotted against time. The length of time intervals resulted from the required precision of the volumetric flow rate measurements. The number of the counted pulses need to be large enough to reduce the measurement error of flow below 1 ml/min for a single flowmeter.

The user interface is simple and intuitive. The Auto Scale button scales the charts to display the minimum and maximum values of the measured parameters. The Save button exports the data to CSV files and overwrites the existing files (if present). The CSV files can be opened in Microsoft Excel, or in another similar program, and recalculated or plotted. The Clear All button deletes the data, after using it all the unsaved information will be lost.

The monitoring of birch sap concentration process can help to analyse a number of aspects of the investigated process. First of all, it provides the essential data that can be used for the modeling of the reverse osmosis process. It simplifies the experiments testing the impact of the working pressure and the starting composition of the feed solution on: (i) flow of the streams, (ii) efficiency of the process, (iii) specific energy consumption and (iv) time needed for the concentrate production. These technological aspects exert deep impact on the economics of birch sap concentrate production.

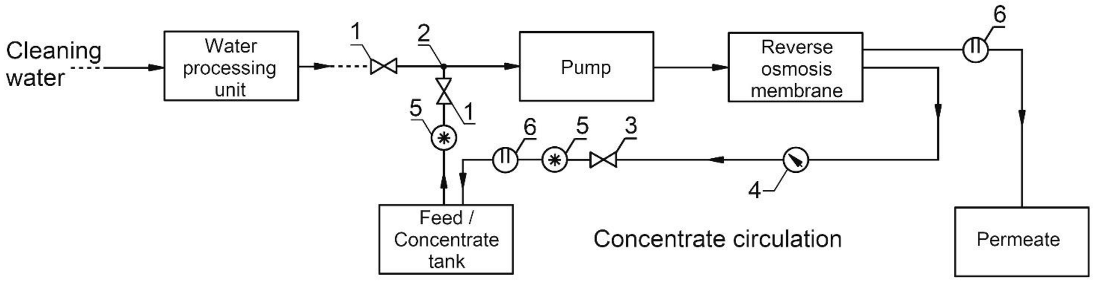

Fig. 1. Location of sensors in the reverse osmosis apparatus: 1 - ball valves, 2 - tee connector, 3 - throttle valve, 4 – manometer, 5 – flowmeters, 6 – conductivity sensors

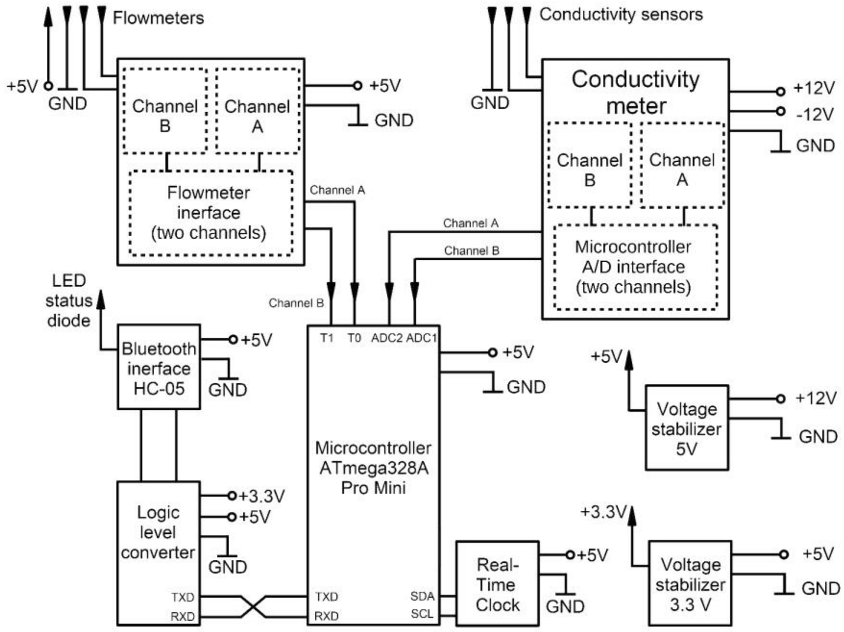

Fig. 2. The block diagram of data acquisition system

Apart from the theoretical significance, the presented new data acquisition system is a convenient tool for solving the practical problems. Real-time monitoring of the volume flow allows for precise adjustment of working pressure by the throttle valve. The small pressure changes could cause significant flow changes. The birch sap composition changes during the tapping season and shows high intraspecies variability [9]. The presented monitoring system helps to compensate for the variability of the raw material and change the parameters to optimise the concentration process.

The device can simplify more complex, i.e. two-stage, experiments [14]. In the first step the batches of unprocessed sap are concentrated to around 2%. After the pre-treatment stage, the concentrates obtained from different batches are combined and concentrated again, preferably at higher working pressure. This procedure can ensure a relatively large volume of the highly concentrated product. Alternatively, pressure can be changed in a one-stage process after the permeate flow becomes too low. This action will increase the final concentration of the product.

The monitoring system improves safety of the operation and prevents damage of the osmotic membrane. The permeate recovery (ratio of the permeate flow to feed flow) have to be checked and should not exceed the nominal value. This procedure is important in the cases when a higher working pressure is applied. Additionally, our device allows to control the permeability of the membrane. The increased conductivity of the permeate stream can be immediately detected and may be the evidence that the RO module has been damaged. The decrease of concentrate flow rate may be a symptom of the solute deposition or be caused by other undesirable effects.

The presented data acquisition system applications do not cover all the possible uses of the device. Thanks to its flexibility, it can be used for other purposes as well.

CONCLUSION

The presented data acquisition device was built in accordance with the latest trends in technology. It provides an easy way to monitor the reverse osmosis system. It is inexpensive (costs of the parts are around 150 Euro or less, year 2018) but powerful and easy to modify. The most expensive parts were sensors (around 90 Euro). The data acquisition device, after suitable changes, may be adapted to larger reversed osmosis systems. It could be used to control the experimental works or help to monitor parameters in standard working conditions.

DISCLAIMER

The source-codes and schematics of the electronic circuits presented in this work and in the Supplementary Materials have been carefully checked. However, we do not take any responsibility for possible errors and any damage they might cause.

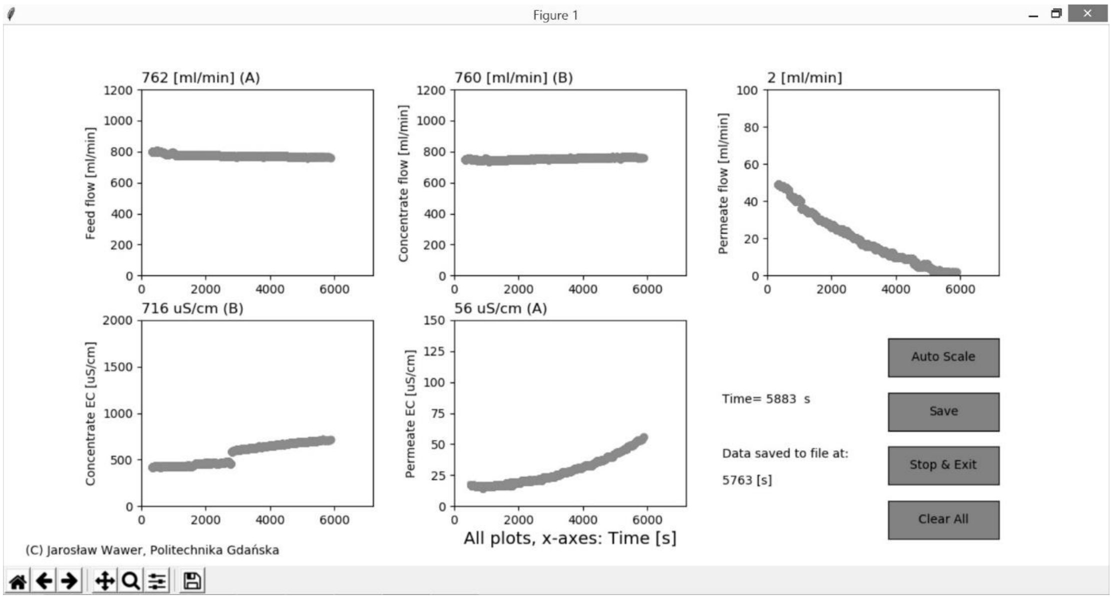

Fig. 3. The screenshot of Python application user interface used for the monitoring of birch tree sap concentration. The concentration process is conducted at room temperature, working pressure: 2.1-2.3 bar, initial volume of birch sap: 4800 ml, reversed osmosis membrane: 100 GPD

REFERENCES

1. **Bilek M. 2018.** Is it worth to collect birch tree sap? Agro Podkarpacie 3, 20-21 (in polish).
2. **Bilek M., Szwerc W., Kocjan R. 2017.** Heavy metals (Pb, Cd, Cr, Ni) content as a potential risk factor, limiting birch tree sap usefulness. Post. Fitoter., 18, 183-189.
3. **Jeong, J., Jeong, H., Woo, S., Shin Ch. 2013.** Consequences of ultrafiltration and ultraviolet on the quality of white birch (Betula platyphylla var. japonica) sap during storage. Austr. J. Crop Sci., 7, 1072-1077.
4. **Bilek M., Vietoris V., Ilko V., 2016.** Shelf life extension and sensory evaluation of birch tree sap using chemical preservatives. Potravinarstvo, 10, (1), 499-505.
5. **Bilek M., Piekarz S., Olszewski M., Sosnowski S. 2017.** Microfiltration as the effective method for extending shelf life of birch tree sap. Post. Nauk. Techn. Przem. Rol. Spoż., 72, 68-76 (in Polish).
6. **Bilek, M., Olszewski, M., Gostkowski, M., Cieślik, E. 2016.** The usefulness of birch saps from the area of Podkarpacie to produce birch syrup. Biotech. Food Sci., 80, 11-18.
7. **Kallio H., Ahtonen S., Raulo J., Linko R. R. 1985.** Identification of the Sugars and Acids in Birch Sap. J. Food Sci., 50, 266–269.
8. **Ahtonen S., Kallio H. 1989.** Identification and seasonal variations of amino acids in birch sap used for syrup production. Food Chem. 33, 125-132.
9. **Bilek M., Szwerc W., Kuźniar P., Stawarczyk K., Kocjan R. 2017.** Time-related variability of the mineral content in birch tree sap. J. Elem., 22, 497-515.
10. **Bilek M., Stawarczyk K., Łuczaj Ł., Cieślik E. 2015.** Content of Selected Minerals and Inorganic Anions in Tree Saps from Podkarpacie Region. Żywn. Nauk. Technol. Ja., 100, 138-147.
11. **Bilek M., Pytko J., Dżugan M., Sosnowski S. 2016.** The possibility of shelf life extension of birch tree sap by creating a beverage with improved taste and health-promoting properties. Post. Nauk. Techn. Przem. Rol. Spoż., 71, 5-19 (in Polish).
12. **Semjonovs P., Denina I., Fomina A., Patetko A., Auzina L., Upite D., Upitis A. Danilevics, A. 2014.** Development of birch (Betula pendula Roth.) sap based probiotic fermented beverage. Int. Food Res. J. 21, (5),1763-1767
13. **Kallio H., Karppinen T., Holmbom B. 1985.** Concentration of birch sap by reverse osmosis. J. Food Sci., 50, 1330-1332.
14. **Wawer J., Bilek M. 2017.** Simple reverse osmosis apparatus for the concentration of the local birch tree sap. Post. Nauk. Techn. Przem. Rol. Spoż., 72, 51-67 (in Polish).
15. **Bilek M., Wawer J., Szwerc W., Słowik K., Sosnowski S. 2018.** Birch sap concentrate as a potential modern food product. ECONTECHMOD 7, (1), 5–9.
16. **Wawer J., Bilek M., Sosnowski S. 2018.** The energy consumption during the birch tree sap concentration process using the reverse osmosis system. ECONTECHMOD 7, (1), 151–155.
17. **Yoon S., Jo J., Kim T. 1992**. Utilization and tapping of the sap from birches and maples. Mokchae Konghak, 20, 15-20.
18. EC/TDS/PPM Meter On Limited Budget, http://www.octiva.net/projects/ppm/ (access 20.09.2018)
19. Arduino Pro Mini, https://www.arduino.cc/en/Main/ArduinoBoardProMini?setlang=it (access 21.09.2018)
20. Bluetooth + mikrokontroler, http://mikrokontrolery.blogspot.com/2011/03/Bluetooth-HC-05-Opis-modulu.html (access 21.09.2018)
21. ResearchGate, DOI: 10.13140/RG.2.2.29173.42729
22. ResearchGate, DOI: 10.13140/RG.2.2.14912.79364
23. ResearchGate, DOI: 10.13140/RG.2.2.26656.84487