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APPLICATION OF HEAT PUMPS IN RAPESEED OIL PRODUCTION

Summary

The production of rapeseed oil requires a lot of energy. Before being pressed, seeds are conditioned, i.e. heated up to the process temperature for the whole mass. Then, as a result of pressing the extracted oil has a higher temperature compared to the ambient temperature. The objective of the study was to assess the application of heat pumps to reduce the energy consumption of the vegetable oil production process. The article analyses the results of the industrial experiment in which a heat pump was employed to cool down oil and heat up rapeseeds before pressing. As part of B+R project No INNOTECH-K2/IN2/5/181835/NCBR/13, a prototype system was constructed with a capacity of 1.5 Mg of oil per hour. The research shows that the return on investment in the heat pump is maximum 2 months. Profit from heating seeds with heat obtained from oil cooling is about PLN 760,000 per annum in the analysed case.
***Key words**: heat pump, rapeseed oil, rapeseed, oil extraction*

ZASTOSOWANIE POMP CIEPŁA W PRODUKCJI OLEJU RZEPAKOWEGO

Streszczenie

Produkcja oleju rzepakowego wymaga dużych nakładów energii. Przed tłoczeniem nasiona są poddawane kondycjonowaniu, czyli podgrzewaniu w całej masie do temperatury procesowej. Następnie na skutek tłoczenia pozyskiwany jest olej o temperaturze wyższej niż temperatura otoczenia. Celem badań była ocena zastosowania pompy ciepła do obniżenia energochłonności procesu produkcji oleju roślinnego. W artykule przedstawiono wyniki doświadczenia wykonane w skali przemysłowej, gdzie zastosowano pompę ciepła do jednoczesnego schładzania oleju i grzania nasion rzepaku przed tłoczeniem. W ramach realizacji projektu B+R nr umowy INNOTECH-K2/IN2/5/181835/NCBR/13 zbudowano instalację prototypową o wydajności 1,5 Mg oleju na godzinę. Z wykonanych badań wynika, że zwrot inwestycji w pompę ciepła to okres nie dłuższy niż 2 miesiące. Zysk z podgrzewania nasion ciepłem pozyskanym ze schładzania oleju to około 760 tys. PLN rocznie w badanym przypadku.
***Słowa kluczowe**: pompa ciepła, olej rzepakowy, rzepak, tłoczenie oleju*

1. Introduction

The role of the agri-food processing industry is to produce ready-to-eat food from crops. As in any production activity, technologies comprise processes whose proper functioning requires the supply of energy. The production of rapeseed oil is one of the branches of the agri-food processing industry. Its production process involves mechanical or chemical separation of oil from seeds. The production technology consists of several processes: preliminary seed preparation processes, viz.: maceration, conditioning, crushing; specific processes: single- or multi-stage hot or cold pressing, extraction of oil with the use of solvents; refining processes: filtration, de-sliming, bleaching and deodorisation [1]. Oil is pressed by means of screw presses. In this process, seeds are initially crushed and, then, under pressure, oil is separated from the remaining part of the seed. The yield and quality of oil mainly depends on operating parameters of the press [2, 3, 4] and the quality of raw materials [5].

The temperature at which the seeds are pressed is one of the parameters directly affecting the yield and quality of oil. An increase in the temperature of seeds results in an increase in oil yield [6]. The profitability of the production of vegetable oil, except for the purchase price of seeds and taking into account only the price ratios of pressings and crude oil, depends on the ratio between the weight of pressings and oil [7]. The price of oil is three times higher than that of pressings. On the other hand, an increase in the pressing temperature adversely affects the storage of pressings and the shelf life of oil [8, 9]. Successful attempts were made to heat seeds by using microwave technology [10]. Due to its high energy consumption, this method has not been applied in the industry. The equipment powered by fossil fuel is commonly applied to condition seeds.

Electricity is an alternative source of heat for fossil fuels. However, the application of a conventional mains-operated heater is not economically rational. Electric power can be used more effectively to heat seeds by using modern methods, such as heat pumps [11]. This method was published by the Patent Office of the Republic of Poland [12]. The objective of the research was to assess the effectiveness of heat pump application in the process of rapeseed oil production.

2. Research methodology

In order to carry out experiments in real conditions, a prototype of the system with the capacity compliant with the performance of the oil production system was constructed (Fig. 1). The tests were carried out in a production plant with a throughput of 30,000 tonnes of rapeseed per annum.

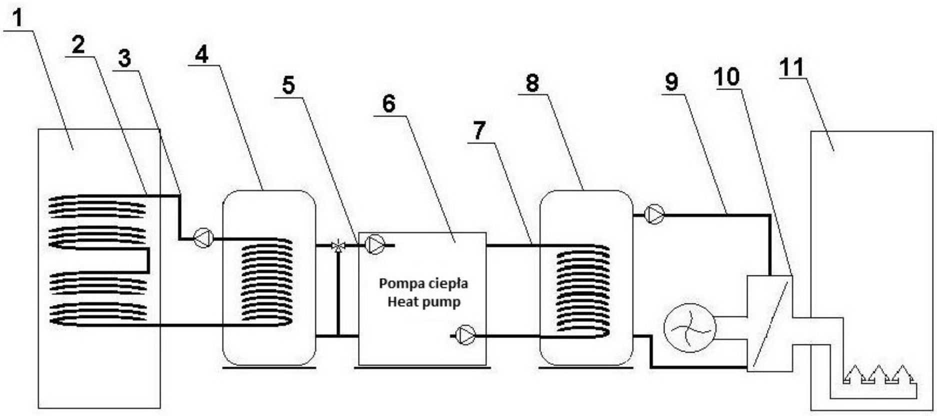

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Fig. 1. Flow chart of the heat balancing station where: 1 - oil cooling tank; 2 - heat exchanger; 3 - lower source loop; 4 - lower source heat buffer tank; 5 - lower source hydraulic system; 6 - heat pump; 7 - upper source heat exchanger; 8 - upper source heat buffer tank; 9 - lower source loop; 10 - liquid-gas heat exchanger with fan; 11 - rape seed buffer tank

Rys. 1. Rys. 1. Schemat blokowy stanowiska do bilansowania ciepła, gdzie: 1 - zbiornik do schładzania oleju; 2 - wymiennik ciepła; 3 - pętla dolnego źródła; 4 - zbiornik buforowy ciepła dolnego źródła; 5 - instalacja hydrauliczna dolnego źródła; 6 - pompa ciepła; 7 - wymiennik ciepła górnego źródła; 8 - zbiornik buforowy ciepła górnego źródła; 9 - pętla dolnego źródła; 10 - wymiennik ciepła cieczowo-gazowy z wentylatorem; 11 - zbiornik buforowy na nasiona rzepaku

A portion of approximately 1.5 Mg of crude rapeseed oil with a temperature above 40°C was pumped into tank No 1 with a volume of 2 m^3. The oil was cooled down until another portion of oil was produced (for about 60 minutes). Heat from oil was transferred to buffer tank No 4 with a volume of 0.5 m^3, filled with a cooling medium with a temperature of 5°C. The thermal energy from the buffer tank was used to supply the heat pump. The heat pump generated thermal energy in the form of a medium with a temperature of 55°C, which was supplied to buffer tank No 8. Heat from tank No 8 was transferred via heat exchanger No 10 to a seed buffer tank with a volume of 10 m^3. The time of heating up seeds was about 90 minutes (Fig. 2).

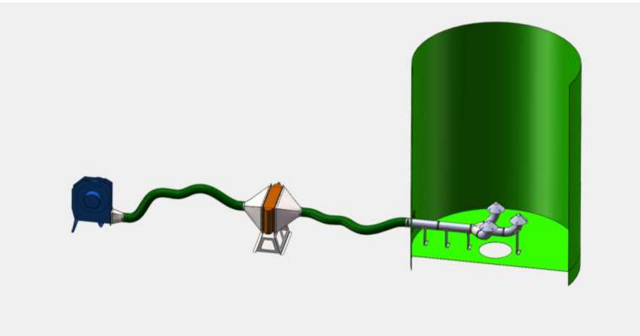

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Fig. 2. Visualisation of the system of pumping heat into the seed tank

Rys. 2. Wizualizacja instalacji do wtłaczania ciepła do zbiornika na nasiona

The electricity consumption of the heat pump was measured with an electricity meter. The dependence of oil yield on temperature was calculated on the basis of data recorded during the oil production within the period of one full calendar year. For this purpose, a control and measurement system dedicated to the prototype system was employed (Fig. 3).

3. Research results

Having reached the operating parameters, the heat pump consumed 2.5 kWh. During the operation of the pump, heat was pumped and collected at an average power of 9 kWh in the same time. This solution get 3,6 kWh cold and 3,6 kWh heat energy from 1 kWh of electricity (Fig 4). Temperature of raw oil after pressing has about 40°C. The oil temperature jest too high for storage. Using this solution is possible cooling the oil to about 20°C and heat rapeseeds to 20°C in the same time (Fig. 4). The rapeseeds temperature in the range 20-35°C is good appropriate for pressing.

The achievement of this effect by using conventional methods in this case (about 4,5 tons rapeseeds per hour), like oil cooling using chiller and rapeseeds heating by conventional heater, this both systems would consume 11.5 kWh_e togheder. Assuming an average energy price of 0.55 PLN/kWh, the difference in costs of consumed energy is PLN 118.00 per day. At 80% of the plant's annual workload, it amounts to PLN 54,000. An increase in the temperature of rapeseed results in an increase in the oil yield. On the basis of the data shown in the graph (Fig. 5), it may be concluded that $\Delta T=10°C$ increases on average the oil yield by 2 Mg per day, *id est* by 7%. The processing power of the plant is stable.

If market prices of 3,000 PLN/Mg for oil and 1,000 PLN/Mg for pressings are taken into consideration, the profit on sale of oil will theoretically increase on average by PLN 4,000 per day. Increasing the temperature of rapeseed above 30°C did not produce the desired effects. The highest profit on the use of heat pumps can be generated in the periods when rapeseeds stored in silos reach a temperature of <10°C. In the period when the research was carried out, the ambient temperatures were record high which affected the temperature of stored rapeseeds (Fig. 6). The temperature of rapeseeds was below 10°C only for 3 months. For half a year rapeseeds temperatures was below 20°C. Hypothetically, using heating pump only on half year (190 days) it is possible to increase revenue by PLN 760,000 in the studied case.

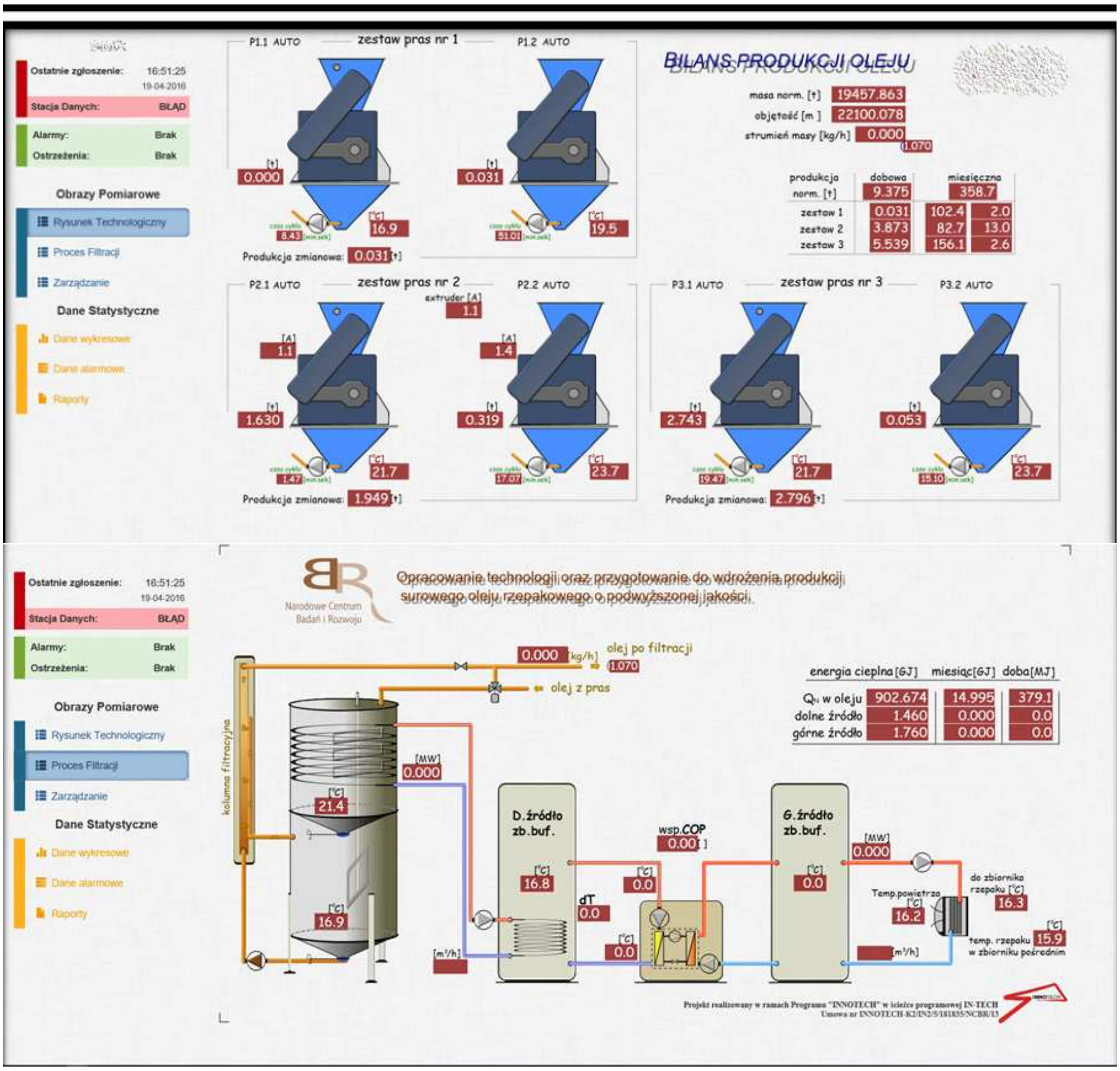

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Fig. 3. View of the control and measurement system panel
Rys. 3. Widok panelu systemu kontrolno-pomiarowego

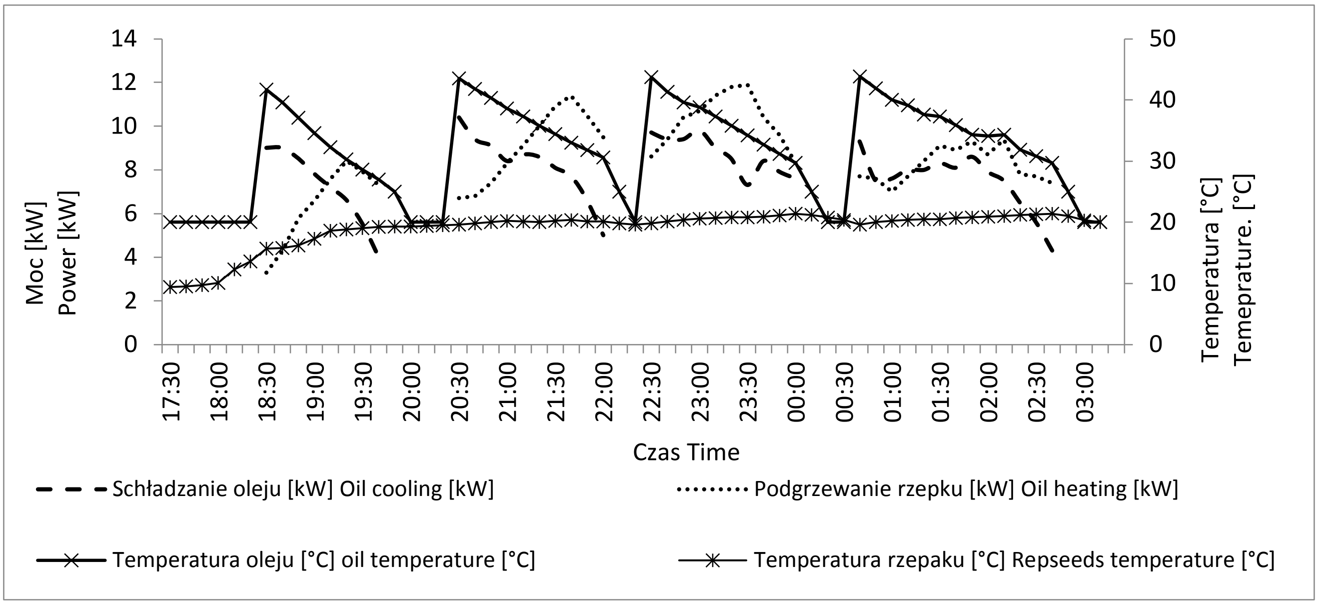

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Fig. 4. Results of heat energy balance and oil and rapeseed flow temperatures during oil production
Rys. 4. Wyniki bilansu energii ciepła i temperatur strumienia oleju i nasion rzepaku podczas produkcji oleju

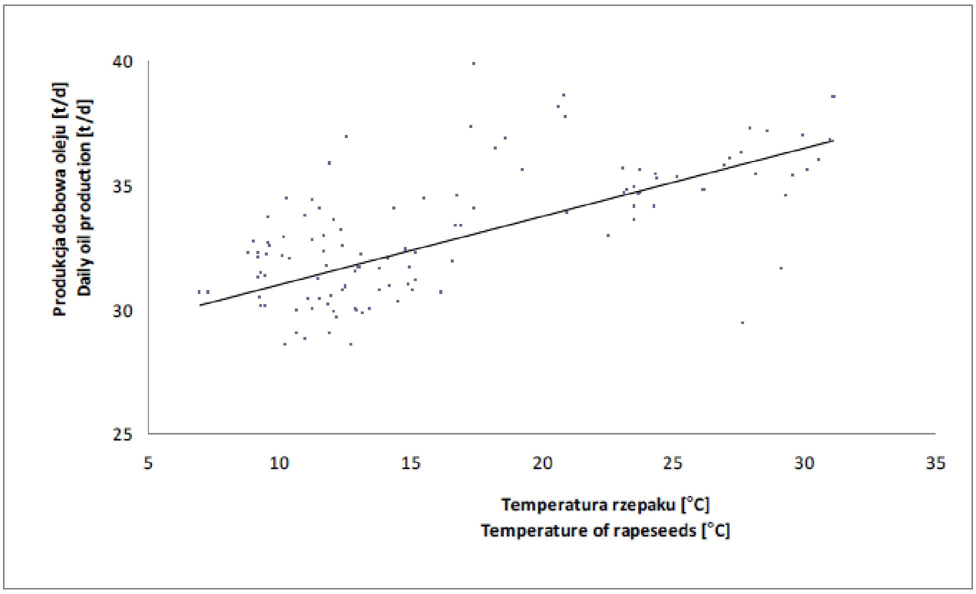

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Fig. 5. Dependence of the quantity of oil produced on the temperature of seeds
Rys. 5. Zależność ilości produkowanego oleju od temperatury nasion

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Fig. 6. Storage temperature of rapeseed at the turn of the calendar year
Rys. 6. Temperatura magazynowanych nasion rzepaku na przełomie całego roku kalendarzowego

4. Conclusions

1. The application of heat pumps in the rapeseed oil production is justified. The simultaneous cooling of oil and heating of rapeseed results in an increase in the oil yield and improves the storage parameters of rapeseed oil.
2. The application of the heat pump in the rapeseed oil production is economically rational. In a fat processing plant with an annual rapeseed processing capacity of 30,000 tonnes, the use of the heat pump instead conventional method may reduce energy costs by PLN 54,000 (only difference between energy consumption) per annum. Further, in the analysed case, an increase in the temperature of rapeseed resulted in an increase in oil yield, theoretically the improvement of production profitability by PLN 760,000 per annum (without depreciation, service and operation costs of heating pump).
3. The cost of investment in the heat pump and the adaptation of buffer tanks should not exceed PLN 200,000, and the operating costs should not exceed PLN 15,000 per annum. The return on investment is 2 months.

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