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THE EFFECT OF CONSTRUCTION AND TECHNOLOGICAL PARAMETERS ON THE EFFICIENCY OF APPLE JUICE PRESSING

Summary

The paper presents the results of the research concerning the efficiency of apple juice processing. In the tests apples of variety Idared were used. Two types of laboratory basket presses were applied. The first one was with perforated cylinder and solid bottom and the second one with perforated bottom and solid cylinder. Pressing was carried out in two modes, continuous and periodic. The yield of juice pressing and moisture content in pomace was determined. The yield of extraction was ranged from 52% to 60.7%. There was significant effect of the load mode on the yield of juice pressing. The yield of extraction in periodic mode was higher than in continuous mode for both of investigated presses. The relationship between the yield of extraction and the pressure of pressing was described by the power law equation. There was no influence of press construction on the pressing yield of apple juice.
***Key words**: pressing efficiency, apple juice, pressure of pressing*

WPŁYW PARAMETRÓW KONSTRUKCYJNYCH I TECHNOLOGICZNYCH NA EFEKTYWNOŚĆ TŁOCZENIA SOKU JABŁKOWEGO

Streszczenie

W pracy przedstawiono wyniki badań nad efektywnością procesu tłoczenia soku jabłkowego. Do analiz użyto jabłek odmiany Idared. Wykorzystano dwa rodzaje pras, prasa pierwsza posiadała perforowany cylinder i pełne dno, zaś prasa druga perforowane dno i pełny cylinder. Proces tłoczenia przeprowadzono w dwóch trybach: okresowym i ciągłym. Określono wydajność tłoczenia i zawartość wody w wytłokach z jabłek. Wydajność tłoczenia zmieniała się w zakresie od 52% do 60,7%. Stwierdzono wyraźny wpływ trybu obciążania materiału na wydajność tłoczenia. Wydajność tłoczenia w trybie okresowym była wyższa w porównaniu z trybem ciągłym dla obu badanych pras. Zależność pomiędzy wydajnością soku a ciśnieniem tłoczenia opisano za pomocą równania potęgowego. Nie stwierdzono wpływu konstrukcji prasy na wydajność tłoczenia.
***Słowa kluczowe**: wydajność tłoczenia, sok jabłkowy, ciśnienie tłoczenia*

1. Introduction

Mechanical expression is an important unit operation commonly used in food processing industry. It is applied for the extraction of juice from fruits and vegetables, dewatering of fibrous materials (sugar beet pulp), extraction of oils from oilseeds and so forth [1, 2]. The raw materials subject to expression are usually semi-liquid or solid masses and contain liquid filled cells, hydrated cell walls, microchannels between cells (plasmodesmata) and intercellular spaces with air [6].

The mechanism of solid-liquid expression from fresh materials is very complex. At the beginning of the process the air is removed and next the liquid is released from the cells. The liquid flows through the capillaries between solid parts. Further increasing the pressure in the material releases new portions of fluid and simultaneously decreases the porosity of the pressing cake. As a results the liquid flow is hindered and expression kinetics decreases [7].

The efficiency of expression depends on following factors: the viscosity of the liquid, the compressibility and porosity of the cake formed, the layer thickness of the pressing materials, the applied pressure and the type of equipment used [1].

In laboratory conditions the expression process is commonly tested with perforated basket presses. These devices have different construction solutions among which there are two basic options. In the first one the fluid flows coaxially to the movement of the piston, they are presses with perforated bottom [4]. In the second solution the liquid flows perpendicularly to the piston movement, they are presses with perforated lateral surface. The flow direction and the thickness of the cake formed can significantly influence the efficiency of the pressing process [3]. Degree of extraction of the liquid depends on the maximum applied pressure, the rate of pressure growth and the duration of load used. A rapid increase in pressure causes sharp decrease in the porosity of the formed layer, which makes difficult to outflow the liquid and reduces the pressing yield [5].

The application of knowledge concerning the expression process is still limited in spite of commonly known factors which can influence on the process efficiency. It is caused by the lack of mathematical relationships between mentioned above parameters and the yield of pressing.

2. The aim of the work

The aim of the work was to investigate the influence of construction and technological parameters on the yield of apple juice.

3. Material and methods

3.1. The raw material

Apples of variety Idared were purchased at a local supermarket (Auchan, Poland). Apples were stored at 4°C before each experiment and were brought up to room temperature 24 h before analysis.

3.2. Pressing

The apples were milled with shredding machine MKJ 250 (Spomasz, Nak³o, Poland) giving particles of about 8 mm. Crushed material was weighed, put in special bags, placed in the press cylinder and then loaded by the piston. The test stand was shown in Fig. 1. Two types of laboratory basket presses were used (Fig. 2).

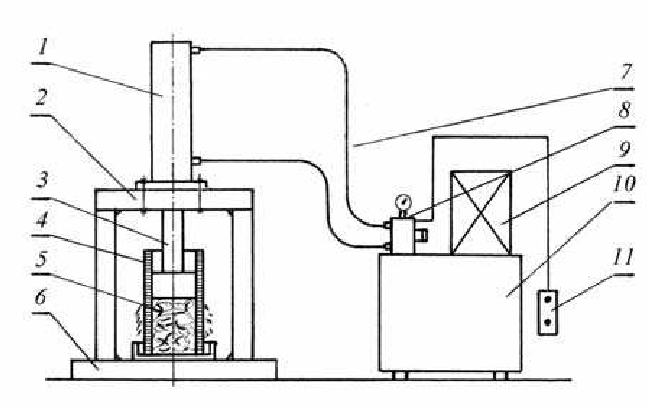

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Fig. 1. Test stand diagramme: 1 – cylinder, 2 – frame, 3- piston, 4 –basket press, 5 – raw material, 6 – base, 7 – conduit, 8 – servo valve with a packing gland, 9 – motor, 10 – container, 11 – guide-pin

Rys. 1. Schemat stanowiska badawczego: 1-cylinder, 2 – rama, 3- tłok, 4 – prasa koszowa, 5 – surowiec, 6 podstawa, 7 – przewód, 8 – serwo-zawór z dławikiem, 9 – silnik, 10 – zbiornik, 11 – pilot

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Fig. 2. Laboratory basket presses used in the research

Rys. 2. Prasy koszowe wykorzystane w doświadczeniu

The first one was with a diameter of 100 mm and a working chamber volume of approximately 600 cm^3. The cylinder of the press was perforated with holes of 3 mm in diameter. The secondary press was with a diameter of 85 mm and a working chamber volume of approximately 150 cm^3. The cylinder of the press was solid and the bottom was perforated with holes of 3 mm in diameter.

Pressing was carried out in two modes, continuous and periodic. For continuous mode the material was loaded with force of 45 kN and next the weight of juice was determined. For periodic mode the material was loaded with forces in the range from 0 to 45 kN, with the interval of 5 kN. The weight of juice was determined after each forces interval

Efficiency of pressing Y_w was determined by the following equations:

$$Y_w = \frac{m_s}{m_{rm}} \cdot 100\%, \qquad (1)$$

where:

m_s – weight of juice,

m_{rw} – weight of raw material.

3.3. Moisture content

Moisture of each sample of apple pomace was determined using drying oven method, by drying a representative 3 g sample in a forced air oven (Sterimatic ST- 11, Instrumentaria, Zagreb, Croatia) at 105°C until the constant mass.

3.4. Statistical analysis

All the experiments were performed in triplicate, and the results were expressed as mean efficiency ± SE (standard deviation). Statistical analysis was performed using Statistica software (Statistica 12, StatSoft Inc., Tulsa, Okla, U.S.A.). Statistical comparisons were made using one way analysis of variance (ANOVA). Differences were considered as significant at $P < 0.05$.

4. Results

In Table 1 the parameters of pressing process in examined basket presses were listed.

The examined presses were different in diameters. Because of this the weight of raw material was selected in that way in order to get the similar compression degrees for both presses.

The value of applied force is one of the most important parameters of mechanical expression. The effect of applied forces on yield of extraction for two kinds of presses was shown in Figure 3.

Table 1. Parameters of pressing process in examined basket presses

Tab. 1. Parametry procesu tłoczenia w badanych prasach koszowych

Type of press	Cylinder diameter [mm]	Weight of raw material [g]	Height before pressing [mm]	Height after pressing [mm]	Degree of compression
Press with perforated cylinder	100	300	98	25	3.92
Press with perforated bottom	85	150	63	15	4.2

Source: own work / Źródło: opracowanie własne

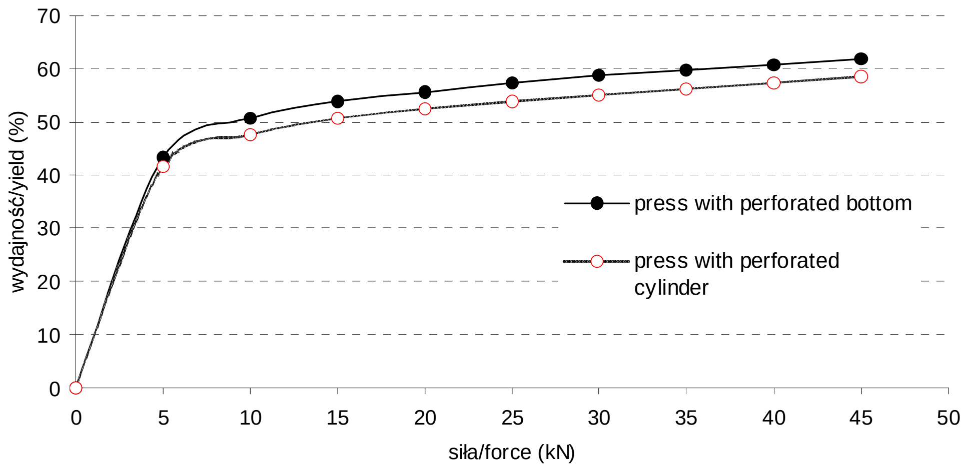

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Fig. 3. The effect of applied forces and type of presses on the yield of apple juice
Rys. 3. Wpływ siły i rodzaju prasy na wydajność soku jabłkowego

The yield of pressing increases with the rise of applied force. The dependency between applied forces and pressing yield was described using power law model:

$$Y_w = a_1 \cdot F^{x_1} \quad (2)$$

where:
Y_w – yield of pressing (%),
F – applied force (kN),
a_1, x_1 – empirical coefficient.

The values of coefficients were listed in Table 2. A very high coefficient of determination is indicator of a good fitting model to the experimental data. The results show that using the same load force the yield of extraction is higher for the press with perforated bottom.

However the used presses had different cylinder diameters which made it difficult to compare the efficiency of their construction. Because of this the applied forces were counted for values of pressure and the yield of pressing was expressed as a function of applied pressure.

The effect of pressure on yield of extraction for two kinds of presses was shown in Figure 4.

The dependency between applied pressure and pressing yield was described using power law model:

$$Y_w = a_2 \cdot P^{x_2} \quad (3)$$

where:
Y_w – yield of pressing (%),
P – applied pressure (MPa),
a_2, x_2 – empirical coefficient.

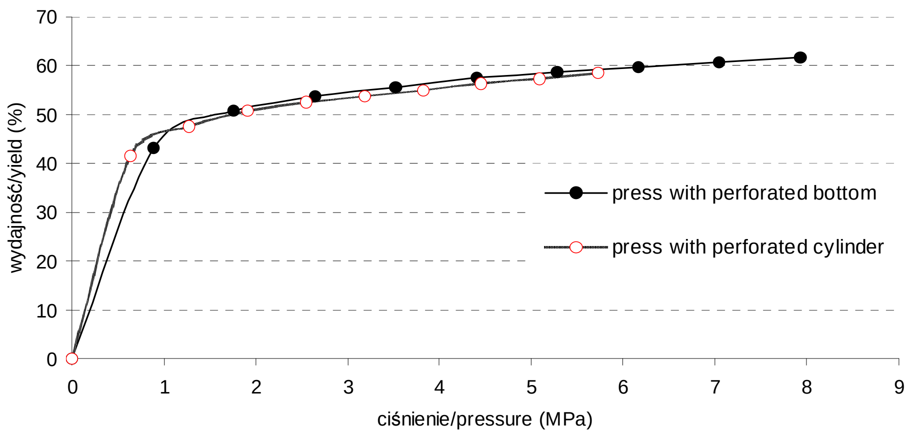

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Fig. 4. The effect of pressure and type of presses on the yield of apple juice
Rys. 4. Wpływ ciśnienia i rodzaju prasy na wydajność soku jabłkowego

Table 2. The parameters of power law model for apple juice pressing
Tab. 2. Parametry równania potęgowego w procesie tłoczenia soku jabłkowego

Type of press	Force (kN)			Pressure (MPa)		
	a_1	x_1	R^2	a_2	x_2	R^2
Press with perforated cylinder	33.618	0.146	0.99	45.409	0.146	0.99
Press with perforated bottom	35.236	0.149	0.99	45.681	0.149	0.99

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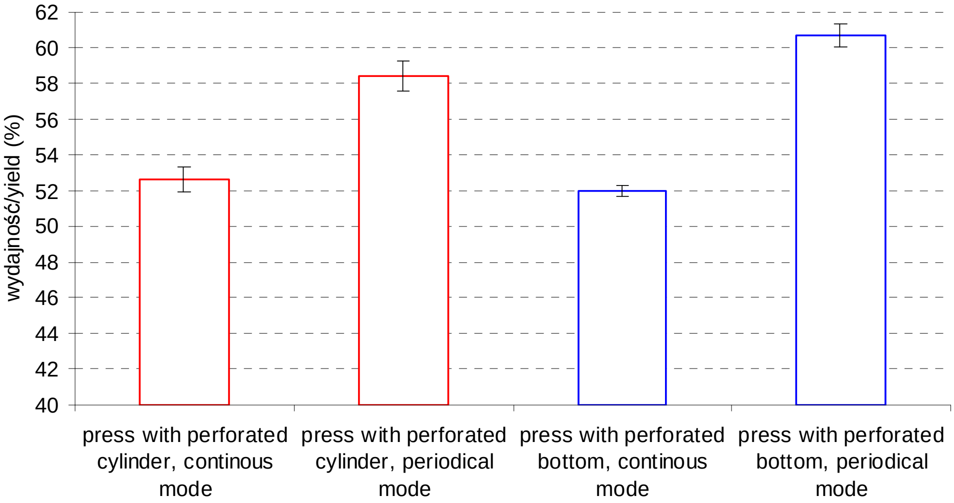

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Fig. 5. The effect of pressing mode and type of presses on the yield of apple juice
Rys. 5. Wpływ sposobu obciążania i rodzaju prasy na wydajność soku jabłkowego

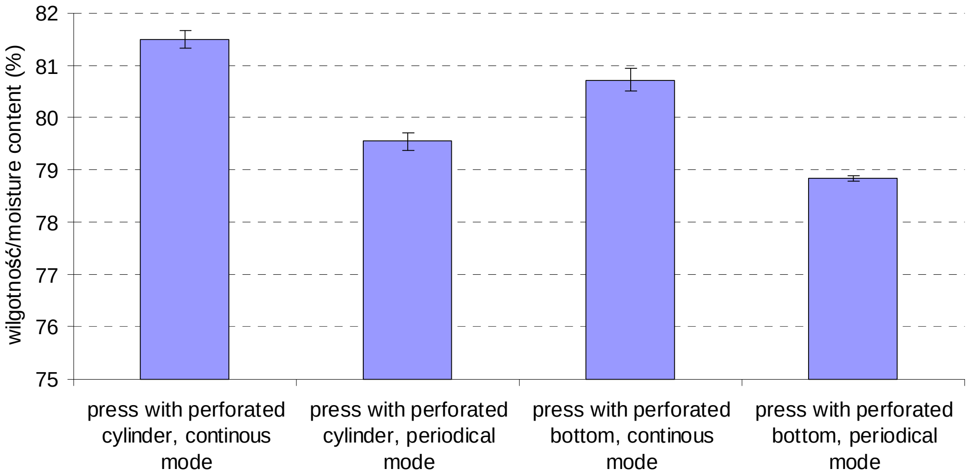

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Fig. 6. The effect of pressing mode and type of presses on moisture content in apple pomace
Rys. 6. Wpływ sposobu obciążania i rodzaju prasy na zawartość wody w wytłokach z jabłek

There is no effect of press type on the yield of pressing. In both cases very similar values of the law power model parameters were obtained.

The influence of pressing mode on the efficiency of apple juice extraction for both presses were presented in fig. 5.

There was significant effect of the load type on the yield of pressing. For both presses the yield of extraction was higher for periodic mode. In the case of the press with perforated cylinder the yield of extraction was higher by 5.8 percentage points, while for the press with perforated bottom by 8.7 percentage points.

The moisture content of pomace is another important parameter of extraction process.

The effect of pressure on moisture content in apple pomace for two kinds of presses was shown in Figure 6.

There was also important influence of load mode on the moisture content in pomace for both type of presses. The lower moisture content was observed for pomace obtained during periodic extraction. In the case of the press with perforated bottom the difference was about 1.85 percentage points, while in the case of the press with perforated cylinder about 1.95 percentage points. The lower moisture content in pomace confirms better extraction of juice from apples.

5. Conclusions

1) The pressing yield of apple juice showed strong nonlinear correlation with applied pressure. The relationship can be described with great accuracy by power law model.
2) There was no influence of press construction on the pressing yield of apple juice.
3) There was significant effect of the load mode on the yield of juice pressing. The periodic mode of pressing increased the yield of extraction about 5.8 percentage points for press with perorated cylinder and about 8.7 percentage points for the press with perforated bottom.
4) There was influence of load mode on the moisture content in pomace for both types of presses. A periodic mode of pressing decreased the moisture content of pomace by 2 percentage points.

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