ANIMAL SCIENCE AND FOOD TECHNOLOGY

Journal homepage: https://animalscience.com.ua/en
Animal Science and Food Technology, 14(4), 58-73
Received 08.08.2023 Revised 03.11.2023 Accepted 22.11.2023

UDC 664.3.032.9
DOI: 10.31548/animal.4.2023.58

Study of the effectiveness of the design of the oil removal channels of screw presses for squeezing out oil

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Suggested Citation:
Hudzenko, M., Vasyliv, V., Zheplinska, M., Sarana, V., & Gorenkov, D. (2023). Study of the effectiveness of the design of the oil removal channels of screw presses for squeezing out oil. *Animal Science and Food Technology*, 14(4), 58-73. doi: 10.31548/animal.4.2023.58.

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Abstract. The relevance of the study is due to the problem that is typical for different types of structures of screw press zeer corps, namely, determining the optimal gap for oil yield, which has practical and economic feasibility. In this regard, this study is aimed at analysing the existing types of zeer corps, identifying their advantages and disadvantages to find methods to improve their design and increase oil yield. The leading methods for solving this problem are empirical research methods, which allow comprehensively considering the existing types of structures based on observation and, through comparison and experiment, to find a rational solution to the problem. The paper analyses the features of technical means for oil separation in presses and extruders, substantiates the practicality of the existing design and indicates the complexity or simplicity of designs in the scientific literature. The need to supplement the existing terms for various designs of the oil separator bodies and possible ways to improve the process of oil separation into different fractions are identified. Experimental studies were carried out with a set of semi-hulls of the zeer sections with different gaps. This made it possible to identify a smaller percentage of cake shedding through the zeer sections, with a corresponding reduction in the gap. The results of oil yield were obtained depending on the established gap in the semi-hulls of the slotted elements of the zeer camera and the heating temperature of the hulls. A decrease in the percentage of shedding with a decrease in the gap in the zeer camera was found. The studied design of the zeer camera type confirmed the versatility and simplicity of its design, which facilitates its maintenance and replacement. For each processed tonne of seeds, due to the increase in the amount of oil squeezed out, the profit of a farmer or enterprise that improves twin-screw extruders by adjusting the gaps as follows will increase accordingly

Keywords: oil production; zeer camera; twin-screw press-extruder; oil output; shedding of oil cake

Introduction

Mechanical pressing or pressing is the most common method of extracting vegetable oils from oil-containing raw materials in all countries of the world. The use of the continuous production method in the design of screw presses and extruders, as well as the ability to convert them to meet production requirements, stimulates the further development of this equipment (Choton *et al.*, 2020). In countries with developed machine building, the technological equipment for oilseed production is, in most cases, universal, and can be used to extract oils from various types of oil-bearing fruits and seeds. Screw presses made by world-renowned manufacturers can be adapted to different types of oilseeds in a short period, depending on the design of the press. Large plants (which have high oil extraction efficiency) use complex equipment that is expensive and always imported. Most of the existing oilseed screw presses for small and medium-sized crushers were designed for a specific type of seed. Therefore, in many developing countries that produce their screw presses for local needs, there is a step-by-step development and improvement of screw presses for pressing oils from several types of oil-bearing fruits and seeds. This will allow farmers and processors to have a machine that can handle many types of oilseeds and will reduce production costs and increase the productivity of their enterprises (Olaoye *et al.*, 2020). In agricultural countries, there is a lack of affordable and efficient solutions for home oil production. The ideal answer to these specific questions is provided by modified screw presses (Gawas *et al.*, 2023).

Screw presses and oil press extruders are simple in design, easy to maintain, and do not require highly skilled technicians to operate. The by-product of oil production, cake, can be used as animal feed (Amiolemhen & Eseigbe, 2019). The safety and simplicity of the whole process is an advantage compared to more efficient solvent extraction equipment. Screw presses used in small-scale agricultural oil mills typically have a capacity of 40 to 200 kg/h. However, screw presses are relatively inefficient, as approximately 10-18% of the oil remains in the cake at the output (Hudzenko *et al*., 2020).

In the work of M. Hudzenko *et al.* (2020) describes the concept of oil and cake separation. The authors distinguish three typical schemes for the design of the zeer corps in screw presses, namely the design of the oil drainage holes in the zeer corps. 1) Drilled holes: This type of oil separation scheme has round holes in the zeer corps for oil drainage. The main advantage of this arrangement is that no additional parts are required for the oil separation system. The zeer corps is manufactured in a monolithic, cylindrical shape. However, the oil separation holes in this system are not adjustable. 2) Tie-down housing with slats. The zeer cylinder is assembled from individual zeer bars, which are fixed in the body frame, forming the inner surface of the zeer cylinder, in which the screw shaft is placed, and the oil is squeezed out. The gaps between the zeer bars are created by installing calibration gaskets between them or by special tides or cuts on one of the zeer bar side surfaces. By using shims of different thicknesses, gaps of different sizes can be achieved. In addition, in this scheme, the set of strips is made in such a way that the inner surface of the zeer cylinder takes the shape of a "brush". This is necessary to ensure that the oil-containing material friction against the cylinder walls, which significantly reduces the possibility of its rotation with the screw shaft. The material must not rotate, as rotation will not cause the material to move translationally along the shaft axis, and therefore no oil will be squeezed out. 3) Sleeve rings: In this type of oil drainage arrangement, the zeer corps consists of flat triangular or hexagonal plates separated by sleeve rings, which are placed on frame tubes. This arrangement allows for greater flexibility in adjusting the press drainage gaps and results in a very simple assembly that can be easily maintained.

Determining the optimal operating parameters of screw presses allows for economical use in terms of labour, energy and operating time, thereby reducing the cost of production. Improving process efficiency and finding alternative methods of machine setup have always been of utmost importance when studying mechanical oil pressing processes. There are many methods that can be used to improve process efficiency, and there are many components and combinations of components that can be used in the process (Bako *et al*., 2020).

Most of the above-mentioned scientific papers on the improvement of screw presses for oil extraction usually consider options for constructive improvement of the geometric parameters of screw shafts, select rational shaft speeds, gaps in the press matrix at the oilcake outlet, temperature limits for heating the oil-containing material or the press body, consider seed moisture, etc. However, the influence of the shape, number, and location of the oil outlet holes in the zeer corps remains poorly understood in scientific papers. When comparing the features of each typical design scheme of the zeer corps of screw presses with the zeer corps of twin-screw press extruders, it was found that the latter have significant differences. Therefore, given that the design of oil extrusion twin-screw presses is poorly studied in the scientific literature, the topic of this paper is relevant.

The aim of the study is to analyse the existing designs of oil drainage channels of screw presses and determine the rational layout of the zeer corps of a twin-screw press extruder for oil extraction.

Literature Review

Mechanical pressing can be defined as a physical process of partial separation of a liquid phase (oil) from a heterogeneous solid-plastic raw material under the influence of external forces. The degree of separation of the liquid phase mainly depends on the design type of the pressing equipment and the properties of the oil-containing raw material to be mechanically pressed (Bako *et al.*, 2017). Due to the complexity of the phenomena that occur during pressing, there is no single theory of the process, and the concepts known so far are only semi-theoretical concepts that seek to summarize aspects observed in the laboratory or during the operation of industrial equipment (Ogunlade & Aremu, 2020).

It is well known that the basic principle of operation of a screw shaft press (Fig. 1) for pressing oil is the movement of oilseeds along the working chamber from the loading mouth and their gradual compression towards the oil-cake outlet chamber. The actual pressing process takes place under the action of an active body (screw or screw shaft), which first compresses the oil-containing raw material in order to eliminate voids with air between its particles. Compression of the oil-containing seeds is carried out by reducing the free volume of the channels of the screw shaft's working area. Increasing the pressing force means reducing the volume of the particles, which leads to the separation of oil from their capillaries, along with the separation of oil on the surface of the particles. It should be borne in mind that the increase in pressure on oil-containing raw materials should be gradual, so that the crushed particles of the solid phase do not clog the capillaries and block the oil flow through the special slots of the zeer camera (Alonge & Jackson, 2019).

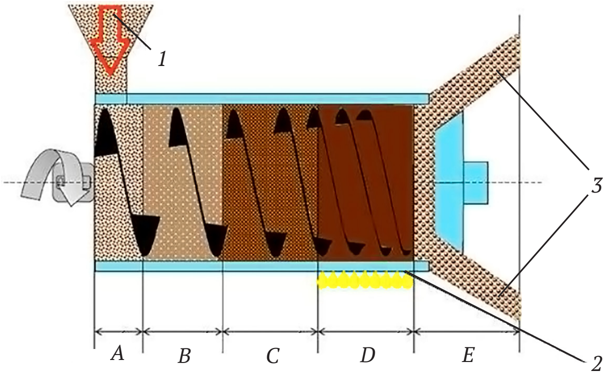

Figure 1. Schematic image of a screw press for pressing oil

Notes: A – power supply zone, B – transportation zone, C – compression zone, D – oil removal zone, D – oil cake exit zone, 1 – oil-containing raw materials, 2 – oil, 3 – oil cake

Source: developed by the authors

In the power supply zone A and transportation zone B of the oil-containing material, there is free space between the seeds. Therefore, air is displaced, and the raw material is compacted in the compression zone. The mechanical compression must constantly increase the compaction of the material and also compensate for the loss of volume when the oil escapes through the openings of the zeer camera. In a single screw press, the material is moved along the screw axis only by friction against the inner wall of the working chamber. The pressure responsible for squeezing the oil is due to the restriction of flow at the press outlet, which causes a pressure gradient that induces a pressure flow opposite to the material flow. The combination of the two flows determines the feed rate, so that the performance of the press depends on the speed of the screw (Alonge & Jackson, 2019). Due to the diversity and complexity of the mechanisms involved in this dynamic process (transport, shear forces, compression, filtration...), the scientific literature suffers from a lack of data on the development of restrictions and oil leakage along the screw. Despite significant recent advances in press design and automation, it remains difficult to predict the performance of continuous pressing based on a theoretical approach (Bogaert *et al.*, 2018).

The process conditions of the screw press have a significant impact on the oil pressing efficiency. These conditions are defined in (Bogaert *et al.*, 2020) as: seed quality, body heating temperature and product outlet temperature, seed feed rate, screw rotation speed and screw profile, which can determine the degree of filling of the screw shaft, friction, and pressure increase. Thus, the effect of pressure on pressing efficiency can be studied by applying different moisture content in the seeds and operating modes (conditions) during the oil pressing process, as well as different screw configurations. For all tested seed moisture content, the oil pressed at 60 and 75°C was higher than the amount of oil pressed at 45°C, and the oil yield improved with increasing pressing temperature.

To obtain high-quality press performance, the seeds or pulp fed into the press must have a certain moisture content and temperature, which depend not only on the type and quality of the raw material, but also on the type of screw press. The parameters of moisture and temperature processing of peppermint and pulp are determined empirically for each individual case. Oil extraction from the pulp takes time. That is, the longer the pressing process, the higher the oil yield. However, as the speed increases, the duration of the pressing process decreases. For this reason, the speed of the screw shaft in modern presses does not exceed 60-70 rpm. Moreover, as shown by the studies described in M. Hudzenko *et al.* (2020), the residual oil content of the pulp decreases rapidly at the pre-pressing stage and slowly at the final pressing stage. A deeper analysis of foreign works (Supriyadi *et al.,* 2019; Chowdhury & Mahmud, 2020; Yate *et al.*, 2020) revealed that most authors (Beerens, 2007; Siregar *et al.*, 2015; Hudzenko *et al.*, 2020) divide screw presses into two main types according to the design of the zeer corps:

1) "hole cylinder press" – perforated cylinder. Oil drainage holes are cylindrical in a monolithic body. They are mainly intended for individual use and small farms. The vast majority of presses of this type operate using cold pressing technology, but before starting work, the body is heated with electric heating elements. Moreover, the outer hole has a larger diameter than the inner one, and can be half the thickness of the casing, while the other half is drilled to the inside of the casing with a smaller diameter. This difference is to prevent it from becoming clogged with oilcake spillage. The oil drainage area is located far away from the oil cake outlet area, as the pressure on the oil cake is highest in the oil cake outlet area. Therefore, if the oil drainage holes are placed close to the oil cake outlet, the oil holes will quickly become clogged with cake. The dry meal comes out of the nozzle. There is a heating system on the oilcake drain. The heat ensures a higher oil yield and a lower residual oil content in the cake. In this type of screw press, different types of seeds can be pressed by changing the nozzle and the speed of the screw shaft (Ionescu *et al.*, 2014).

2) "strainer press" – a tie-down sieve press. The designs of these types of presses are quite diverse, but they are united by common characteristics:

- the zeer sections are mounted along the entire length of the screw shaft (except for the section with the intake coil);
- longitudinal (slotted) oil drainage holes formed by

– the gaps between the zeer bars (grates), which are connected to each other by bars, which in turn are tightened in a special frame;

– the width of the calibration washers between the zeer plates; the protrusions on the bushings of the zeer plates' side surfaces;

– the zeer cylinder is made to be disassembled in the horizontal or vertical plane and consists of separate sections.

In most cases, strainer presses operate using cold pressing technology. However, there are press designs that include frying or electric heating.

The paper by P. Evon *et al*. (2021) describes the advantages of the modular design of twin-screw extruder housings, namely the ability to swap different working sections in the extruder. The authors note the ability to effectively configure the screw depending on the specified needs, using a variety of elements with different screw profiles. The correct choice of a screw configuration kit is an important factor in maximizing the quality of extruded products.

Based on the analysis of scientific papers and websites of screw press manufacturers, it was found that the choice of the zeer body design scheme depends on the designed capacity of the press. Given that twin-screw presses have a capacity of 150 kg/h, it is more appropriate to use a sieve type of the zeer corps. Among the many patents for twin-screw presses, there are often structurally complex zeer cameras (with numerous parts and combined with heating elements), which significantly increase the complexity of manufacturing, maintenance of the structure, and, accordingly, the final cost of the product. Therefore, such factors as ease of maintenance, quick replacement of worn-out parts, and the cost of the zeer sections during the operation of twin-screw presses are crucial for choosing the design scheme.

Materials and Methods

Experimental studies were carried out in production conditions at the enterprise PE "Plasma" in 2019. The equipment of the press line consisted of a serial twin-screw press extruder EK 75/1200 manufactured by SPE "Extruder" (Kharkiv). The main technical characteristics of the EK 75/1200 press extruder are shown in Table 1.

Table 1. *Technical characteristics of the EC 75/1200 press extruder*

Indicator	Size
Productivity (for unthreshed sunflower seeds), kg/h	150-175
Installed power, kW	18.3
Power consumption, kW	up to16
Power of the electric motor, kW	7.5
Power of electric heaters, kW	up to 12
Heating temperature of the housings (depending on the raw material), °C	up to 150
Shaft rotation frequency, rev/min	30-60

Source: passport for the operation of the EC 75/1200 press extruder

The body of the twin-screw press extruder (Fig. 2) consists of successively arranged sections with an impermeable wall (heating sections) 2, 3, 4, 6 and zeer sections 5, 7, which alternate with each other and are bolted together. The working elements of the worms are separate screw nozzles 10 and groups of grinding nozzles 11, offset from each other by 15° to form a screw channel, so that their tops are located along the screw line. The auger shafts of the technological unit are disconnected from the drive shafts. A die 8 is attached to the last zeer section 7, which, together with cone nozzles 9, forms a regulating outlet slot for the cake. Each section with an impermeable wall 2, 3, 4, 6 is equipped with an electric heating element located around its outer wall, which allows for controlled heating of the section walls by adjusting the electric current.

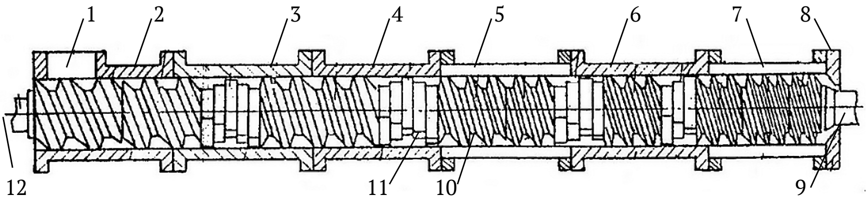

Figure 2. Scheme of the modular design of the twin-screw press extruder

Notes: 1– loading neck; 2, 3, 4, 6 – sections of corps heating; 5, 7 – zeer sections; 8 – matrix; 9 – conical nozzle; 10 – screw nozzles; 11 – groups of cams; 12 — shaft

Source: developed by the authors

The grinding nozzles located inside the heating sections ensure that the processed material is kept at the optimum temperature by intensive mixing inside the section and prevent the seeds from losing their mass in the form of spillage. As the sections with an impermeable wall alternate with the zeer oil-pressing sections, the zeer sections receive a uniformly heated crushed seed mass at the optimum temperature. The walls of the zeer sections are heated by heat transfer from the walls of the heating sections. The design and technological parameters of the experimental press extruder, the geometric parameters of the screw shaft, the composition, and characteristics of the measuring devices are described in (Hudzenko *et al*., 2020).

The drive and the body heating system were controlled from the control panel, which is made as a separate unit. The control panel scheme of the press extruder is implemented on the basis of the Microchip 16F874 microcontroller, with a digital display implemented on LCD indicators that display the values of the set and monitored parameters. During the experiment, the temperature values in two heating zones (the first zone – sections 2, 3, the second zone – section 6), the current consumed by the electric motor and the voltage of each of the three supply phases were recorded. Temperature measurements in the two heating zones of the press extruder body were performed using thermocouples with KTY-81 elements from Philips, and temperature control is carried out using a thermal automation system.

The raw material under study was a batch of whole rapeseed with a moisture content of 8.2%, which was determined by a moisture tester WILE-55 from Farmcomp. The seeds were cleaned on a magnetic and air-sieve separator. The choice of devices and measuring equipment was made on the condition that they ensure the accuracy of measurements regulated by standard methods described in more detail in the work (Hudzenko *et al*., 2020). For the experiment, the mathematical planning methodology developed in the course of previous studies was used, and the central compositional plan of the second order was chosen as the basis. The data obtained during the experiment was processed using the computer software Microsoft Office Excel 2016.

Experimental studies were close to production conditions, so in order not to violate the technological conditions of oil extraction, the flow of seed mass into the extruder hopper was not interrupted, and all measurements were carried out when the extruder reached a steady state. All readings from the control panel were made every minute, and the oil yield was determined by the control unit of time of 10 minutes. During this time, the oil, and cake squeezed out of the press extruder were collected in special containers, which were then weighed using Domotec Plus DT52 electronic scales. The selected oil was settled, and the proportion of oilcake (small particles) in it was determined. Thus, the oil yield was calculated based on equation (1):

$$V_o = \left(\frac{m_{oil\,cake}}{m_o} - m_{shedding\ of\ oil\ cake}\right) \times 100, \quad (1)$$

where V_o – output of oil, %; $m_{oil\ cake}$ – weight of oil cake, kg; m_o – mass of oil, kg, $m_{shedding\ of\ oil\ cake}$ – mass of shedding of oil cake, kg;

All control measurements in this study were repeated three times, and the data obtained were averaged.

Results and Discussion

The housing of twin-screw press extruders is manufactured by SPE “Extruder” in a prefabricated block fashion. It consists of separate sections connected in series: with a feed opening, with impermeable walls (heating sections) and zeer sections (for oil separation). The sieve section of a twin-screw press extruder (Fig. 3) consists of a body-frame 1 and four half-bodies of slotted cylindrical elements 3. The frame of the zeer section (Fig. 3a) consists of three hollow metal plates that are permanently connected to each other at a certain distance. They have mounting holes located at the edges for bolting to other sections of the press extruder body and inside the plates for fixing the bodies of the slotted cylindrical elements.

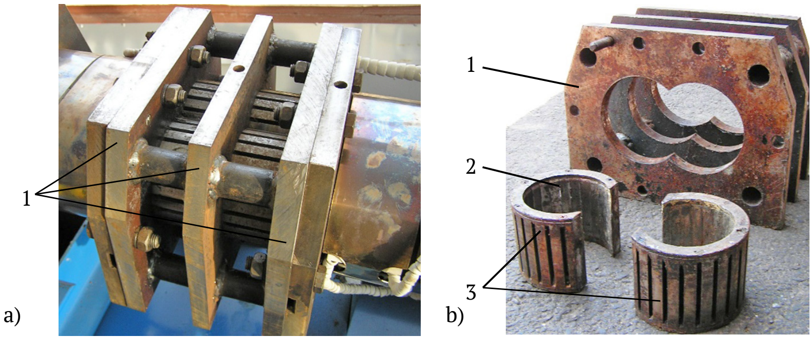

Figure 3. General view of the zeer sections

Notes: a) mounted in the corps of the press-extruder, b) disassembled into component elements; 1 – body-frame; 2, 3 – plate and half-shells of slotted cylindrical elements

Source: developed by the authors

The main body of the zeer camera is formed by assembling two half-hulls of slotted cylindrical elements that are pressed into the body frame. Rigidly connected to each other, they form an internal cylindrical surface, the guide of which is the circumference of two circles of equal diameter, the centres of which are located at a distance less than the diameter of the circle but greater than half of it. This is a characteristic feature of twin-screw press extruders, in which the working bodies are in mutual engagement.

The half-body of the slotted cylindrical element (Fig. 4) is made composite. It has a corps 1 in the form of a half-case of a zeer, which has longitudinal wide slots on the lateral surface from the outside, and is lined with zeer plates 2 from the inside, which are tightly adjacent to each other along the entire length, and in the middle section of the contact have longitudinal grooves, which form slots for oil flow. In this case, the oil slots coincide with the slots of the slotted cylindrical element. The end sections of the plate are rigidly connected to the half-housing by spot welding, and are additionally fixed to the side of the half-housing by flanges 3 with necks. Each flange is attached to the end of the half-hull with screws 4.

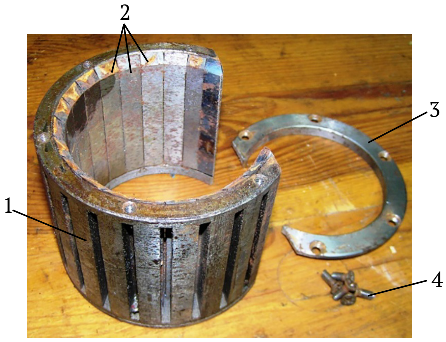

Figure 4. Half-body of a slotted cylindrical element

Notes: 1 – corps; 2 – zeer plates; 3 – flange; 4 — screws

Source: developed by the authors

The advantages of this design of the zeer section include: reliability; ease of replacement of individual worn plates; and quick replacement of slotted cylindrical element bodies. The two-layer design of the slotted cylindrical element half-body, with the inner layer – the zeer plates – resting on the outer body, requires less material costs for repair, as only worn-out plates are replaced. After all, only the inner layer is subject to wear during operation.

The dimensions of the gaps between the plates are determined by the structure of the raw material being pressed and its initial oil content. According to the manufacturer's recommendations, the gap size for pressing rapeseed and sunflower seeds is 0.45 mm. However, during the operation of these types of presses and for experimental studies, half-bodies of slotted cylindrical elements with gaps for the first zeer section of 0.4 mm and the second – 0.2 mm were ordered from the factory. According to the manufacturer's design, there are two zeer sections for the EK-75/1200 press brand, and they alternate with heating sections (Fig. 5).

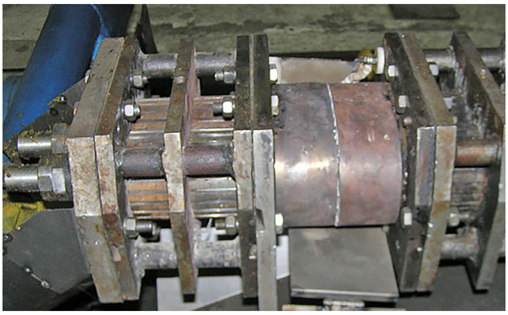

Figure 5. Location of zeer chambers during experimental studies on EK-75/1200 extruders

Source: developed by the authors

In most of the papers with experimental studies (Evon *et al.*, 2016; Carré, 2022), the oil pressing process was carried out under different operating conditions to evaluate their impact on oil yield, press capacity, energy consumption, etc. In S.M. Sheikh & K.S. Zakiuddin (2019), a report is compiled to provide some insights into oil pressing technology that can help improve rural development in terms of oil extraction by small-scale crushers. Different types of designs and advanced developments are described in detail, with operating parameters and mechanisms used. Their analysis is useful for designing similar equipment, and the trends in the influence of various factors of the press's design parameters on oil yield are described. For example, when processing Jatropha curcas L. seeds using a screw press, the variables studied were the extraction temperature (50°C, 70°C and 90°C), screw speed (40 rpm, 50 rpm and 60 rpm) and the diameter of the hole in the press die (11 mm, 12 mm and 13 mm). As a result, the highest oil yield was obtained at the highest temperature, lowest rotational speed, and using the smallest die bore diameter (Yate *et al.*, 2020). As expected, the performance of the screw press decreased as the oil yield increased, but the energy consumption remained almost unchanged over the evaluated range of operating conditions. The prevailing conditions were 90°C, 40 rpm and an 11 mm diameter outlet nozzle for the oilcake. However, these are complex and challenging studies.

In the work of K. Alabi *et al.* (2022), authors describe in detail the methodology for calculating the design of a single-screw press for pressing palm oil. However, in such works, the optimization of the size of the gaps in the zeer cameras is not specified. The authors point out that their press is simple in design, easy to operate and maintain. However, they agree that the technology of oil production on their press needs to be further optimized. Future work should investigate the impact of pressing process variables (such as time and temperature) on oil yield and productivity.

The validity of the choice of the initial variable parameters adopted by us is confirmed by the research and conclusions presented in M. Mursalykova *et al.* (2023). The authors argue that under the initial conditions, the yield of safflower oil increased with a decrease in moisture content, the size of the oil outlet channel, and a decrease in rotation speed. However, this is not enough to obtain the optimal parameters of the process under consideration. To make a final decision on the choice of optimal modes of the process under study, it is necessary to conduct a series of experiments on changes in humidity, pressure, and temperature. The authors also note that when the humidity drops below 8%, the yield of safflower oil decreases due to an increase in the temperature of the oil press, as the oil "burns out". Increasing the moisture content above 10% also reduces the oil yield, as excess moisture makes it difficult to press the cake efficiently.

To obtain a more reliable assessment of the experimental results for the twin-screw press extruder, as established in previous studies described in (Hudzenko *et al.*, 2020), the initial variable parameters were the heating temperature of the housings. The size of the gap in the die was set to 4.2 mm, and the shaft speed was set to 42 rpm. These values were left with the values obtained in previous studies, because at these values, an increase in oil yield was observed. During the experiment, the following scheme of the arrangement of the zeer sections and the size of the gaps in them was used (Table 2).

Table 1. *The scheme of setting gaps in the zeer sections of the EK 75/1200 press extruder*

No. of the experiment	The size of the gaps of the gap in the zeer sections, mm	
	The first zeer section	The second zeer section
1 Experiment	0.4	0.4
2 Experiment	0.4	0.2
3 Experiment	0.2	0.2

Source: developed by the authors

Based on the obtained experimental results and computer processing, the graphical dependence of the yield of rapeseed oil on the size of the gap in the zeer sections (Fig. 6) at different heating temperatures of the housings is shown.

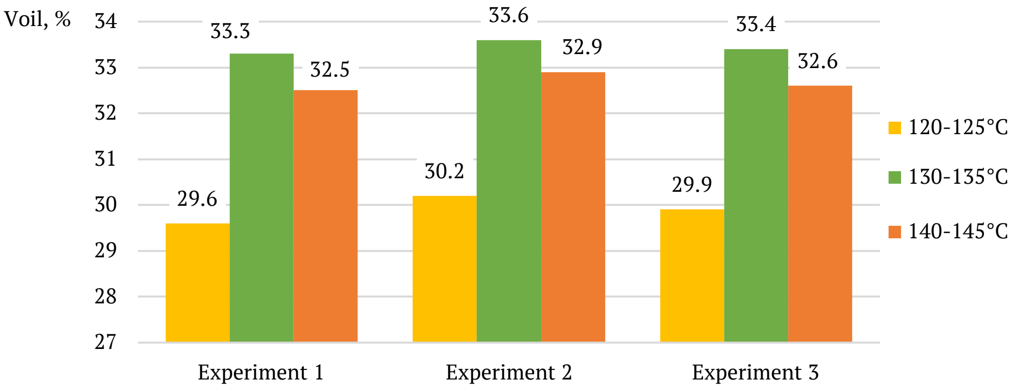

Figure 6. Dependence of the yield of rapeseed oil on the size of the gap in the zeer section at different temperatures of heating the housings

Source: developed by the authors

When comparing the obtained values of rapeseed oil yield, the effectiveness of using reduced gaps in the zeer cameras (experiment 2 and experiment 3) is obvious. However, when a gap of 0.2 mm was set in the first oil filtration zone (experiment 3), a slight decrease in the percentage of oil and more sintering of the cake petals was observed. At different heating temperatures of the press extruder body, the temperature of the oil at the outlet of the extruder was fixed at 87-100°C.

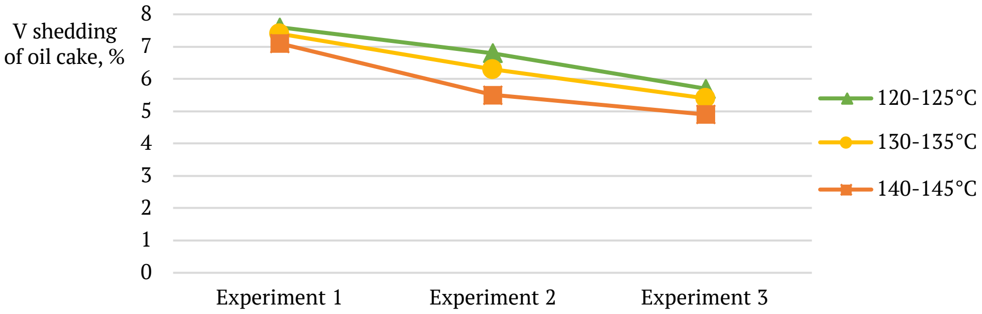

Figure 7. Dependence of the yield of fallout (small cake particles) of rapeseed oil through the slits in the zeer section at different temperatures of heating the housings

Source: developed by the authors

It should be noted that the percentage of oilcake shedding decreased with a decrease in the size of the gap (experiment 2 and experiment 3), and there is a general tendency to its decrease with an increase in the temperature of heating the shells. Thus, considering the obtained indicators of oil yield, for further operation and further research, the value of the gaps of the zeer cameras that was adopted in Experiment 2 will be selected.

In the work of C. Cravotto *et al.* (2023) focuses on the advantages of the modular design of twin-screw extruders. An improved design of a twin-screw extruder is described and proposed as an innovative process for oil extraction with a combination of extraction process. Modified twin-screw extrusion processes with solvent injection pumps were evaluated. The solvents tested included water, phosphoric acid-acidified alcohols, and fatty acid methyl esters (FAME). Among them, FAME proved to be the most effective extraction solvent, recovering up to 98% of the total oil (based on the residual oil content of the meal). Because two separate filtration modules (zeer cameras) can be separated to produce a first filtrate consisting of the pressed oil from the pressing stage and a second filtrate after the solvent extraction stage. These combined processes have great industrial potential due to their efficiency and flexibility. However, the analysed papers on twin-screw extruders did not reveal any studies like ours. The work of M. Ionescu *et al.* (2015), in which the quantitative distribution of oil along the zeer camera was studied during oil extrusion on a single-screw press of low capacity.

In the work of W. Li *et al.* (2007), the authors noted the disadvantages of single-screw presses for pressing rapeseed oil, and a double-screw press was developed to implement cold pressing of peeled rapeseed seeds with double low hulling. Multistage compression was used in the pressing chamber, and the geometrical parameters of the path ensured a relatively thin layer of oil-containing material during pressing. The total theoretical compression ratio of the twin-screw press was 23.0, and the ratio of the length to the diameter of the pressing chamber was 11.5, with the pressing time extended to 180 s. The oil content of the cold-pressed cake from the cleaned rapeseed was about 15%. The cold pressed cake was obtained at a temperature below 70°C, which met the requirements of the cold pressing process. Two screws rotated in different directions, and the zeer corps was of the sieve type with longitudinal holes. The press capacity was 45 tonnes per day.

The advantages of the modular design of twin-screw extruders allow for the arrangement of the zeer cameras in several ways: placed alternately behind the heating chambers, or one after the other at the end. Therefore, in further studies, it is advisable to conduct additional experiments by mounting the zeer sections one after the other at the end of the body, while investigating the quality and percentage of oil yield.

Conclusions

The study obtained new scientific results that expand the understanding of the regularities of the process of oil squeezing in twin-screw press extruders through the gaps of the zeer camera at different sizes. The studies experimentally confirmed that the oil yield depends on the temperature in the working area of the press extruder and the size of the gap in the zeer camera. In experiment 1, with a gap in the zeer camera of 0.4 mm and an increase in the heating temperature of the extruder body from 120 to 135°C, an increase in oil yield from 29.6 to 30.2% was recorded. And with further heating to 145°C, the oil yield decreased to 32.5%. In experiment 2, with a gap in the zeer cameras of 0.4 mm and then 0.2 mm, with an increase in the heating temperature of the extruder body from 120 to 135°C, an increase in oil yield of 2.1% was recorded. In experiment 3 (with further heating to 145°C), a slight decrease in oil yield by 0.1-0.3% was recorded. At the same time, the percentage of oilcake shattering with a decrease in the size of the gap of the zeer cameras from 0.4 mm to 0.2 mm decreased from a maximum of 7.6% to 5.7%, i.e. by 2.2%. Thus, the general nature of the change in the size of the outlet gap in the zeer sections affects the oil yield and the percentage of oil cake shattering. However, these parameters should be considered in conjunction with other design parameters of the press extruder to investigate the energy consumption of the oil extraction process. In twin-screw press extruders with a capacity of 100 kg/h or more, it is more appropriate to use a sieve type of zeer corps. Among the many patents for twin-screw press extruders, there are often structurally complex zeer cameras (with many parts and combined with heating elements), which significantly increase the complexity of manufacturing and maintenance of the structure, and, accordingly, the final cost of the product. Therefore, such factors as ease of maintenance, quick replacement of worn parts, and the cost of zeer sections during the operation of twin-screw press extruders are crucial for choosing its design scheme.

Based on the results of this study and the analysis of similar works, further research will be promising in clarifying the percentage of oil squeezed out of each individual zeer section. And also, given the modular design of the press extruder body sections, it was concluded that in further research it is also possible to mount the zeer sections one after the other at the end of the body, while examining the quality and percentage of oil yield. Overall, the twin-screw press extruders have achieved significant improvements in oil yield and quality.

Acknowledgements

None.

Conflict of Interest

None.

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Дослідження ефективності конструкції олієвідвідних каналів шнекових пресів для відтискання олії

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Анотація. Актуальність дослідження зумовлена проблемою, яка характерна для різних видів конструкцій зеєрних корпусів шнекових пресів, а саме визначення оптимального зазору для виходу олії, що має практичну і економічну доцільність. У зв'язку з цим дане дослідження спрямоване на аналіз існуючих типів конструкцій зеєрних корпусів, виявлення їх переваг і недоліків з метою знаходження методів до вдосконалення їх конструкції та збільшення виходу олії. Провідними методами для вирішення цієї проблеми є емпіричні методи дослідження, що дозволяють на основі спостереження комплексно розглянути існуючі типи конструкцій та шляхом порівняння і експерименту знайти раціональний варіант розв’язку поставленої задачі. В роботі проаналізовано особливості технічних засобів для відділення олії в пресах та екструдерах, обґрунтовано практичність існуючої конструкції та вказано на складність чи простоту конструкцій в науковій літературі. Виявлено необхідність доповнення існуючих термінів до різноманітних конструкцій зеєєрних корпусів, та можливі шляхи вдосконалення процесу відділення олії на різні фракції. Проведено експериментальні дослідження з набором півкорпусів зеєрних секцій з різними зазорами. Це дозволило виявити при відповідному зменшенні зазору менший відсоток осипки макухи через зеєрні секції. Отримано результати виходу олії в залежності від встановленого зазору в напівкорпусах щілинних елементів зеєрної камери від температури нагріву корпусів. Виявлено зменшення відсотку осипки зі зменшенням зазору в зеєрній камері. Досліджена конструкція типу зеєрної камери підтвердила універсальність і простоту її виконання, що полегшує її обслуговування та заміну. З кожної переробленої тони насіння, за рахунок збільшення кількості відтиснутої олії, відповідно, зросте і прибуток фермера чи підприємства, які вдосконалять двогвинтові екструдери відрегулювавши зазори вказаним чином

Ключові слова: виробництво олії; зеєрна камера; двогвинтовий прес-екструдер; вихід олії; осипка макухи