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# AUTOMATION OF THE OIL EXTRACTION PROCESS PERFORMED BY MEANS OF A SCREW PRESS

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**Abstract:** The continuous development of the oil-manufacturing industries causes the necessity of improving extraction technologies. In this case, the specific interest is focused on the control systems of screw presses. Among a great variety of such machines, the small household presses are in significant demand among consumers. Various seeds and kernels require different technological conditions to be provided in order to maximize the qualitative and quantitative characteristics of the extracted oil. Therefore, the main objective of this research is developing and testing the control system allowing for automation of the oil extraction process. Particularly, the temperature parameters of the pressing chamber, extracted oil, and electric motor are to be monitored and limited. In addition, the consumer should be able to predefine the mass of the oil to be extracted. Considering the small household screw press LiangTai LTP200, the general algorithm (block diagram) of the control system operation is proposed and the corresponding experimental prototype is developed. The latter is based on the Arduino Mega microcontroller and is equipped with three temperature sensors, two coolers (fans), one heater, and one mass sensor. The proposed control system allows for continuous monitoring and limiting of the pressing chamber, oil, and electric motor temperatures, as well as the mass of the extracted oil. The experimental data show that the pressing chamber preheating process lasts for about 3 min (170…190 s) and its maximal temperature does not exceed 44°C. The temperature of the extracted oil does not rise over 61°C. The motor temperature changes within the range of 69...71°C. The oil extraction productivity is as follows: 1.2 kg/h (sunflower seeds), 1.06 kg/h (walnut kernels), 0.9 kg/h (almond kernels), and 0.78 kg/h (peanut kernels). The obtained results can used in further investigations focused on analyzing the influence of these parameters on the quantitative and qualitative characteristics of the extracted oil.

**Key words:** pressing chamber, experimental prototype, Arduino microcontroller, cooler, heater, asynchronous motor, productivity

## 1. INTRODUCTION

Nowadays we observe the constant growth of interest in the production of oil. Hence, the search for innovative and even more efficient extraction methods becomes quite an important task. There are various technologies available so far. The classic press that extracts oil from vegetable raw materials is becoming the subject of intensive scientific study and technological improvement. The effectiveness of oil extraction depends on a number of factors, such as press design, compression ratio, and a set of optimal conditions for each type of raw material. The high level of mechanization and the possibility of using various types and configurations of presses for different raw materials offer a potential for enhancing the production of oil from vegetable sources. To improve press design and optimize technological parameters, it is important to conduct investigations of the oil extraction process at different press configurations and extraction conditions.

Existing studies allow us to identify ways for the next steps in research and development in the use of the press for oil extraction, as well as to note its advantages in the context of sustainable and efficient production of vegetable oils. Analysis of existing literature provides us with useful information on oil production and its effect on product quality. Seed oils play a crucial role in both the food and industrial sectors, including biodiesel production. As shown by Choton S, Gupta N et al. in [1], the extrusion technology proves to be cost-effective and efficient, facilitating the production of diverse products while ensuring high quality and the preservation of essential substances. The content of the article [2] written by Nde DB and Anuanwen CF explores optimization techniques, delineating their benefits and examining various modeling methods employed in optimization processes. Enhancing oil recovery is a key aspect of improving product quality and overall yield. In [2], Nde DB and Anuanwen CF emphasize the influence of these methods on the quality of the resulting oil.

Another important aspect described in sources [3] written by Frangipane MT, Cecchini M et al. [4] authored by Guerrini L, Breschi C et al. and [5] by García-González A, Velasco J et al. is the process of oil filtration and its influence on the chemical and sensorial characteristics of the product. The lack of filtration leads to defects and deterioration of quality within a short time, which can reduce the commercial grade of the oil. Filtration during the first few days significantly reduces this risk, ensuring better quality of the oil and preserving it during long-term storage. In [6], the authors Mridula D, Saha D et al. made experiments on optimizing the parameters of oil extraction from cleaned and whole sunflower seeds at different levels of humidity and temperature of the press head. The box-Behnken method was used with 60-80 g. of cleaned seeds, 20-40 g. of whole seeds, and 6-10% humidity at 50-90°C. As a result, optimum conditions were defined as: 68.64% cleaned seeds, 31.36% whole seeds, and 6% moisture at 71.5°C press head temperature for extracting sunflower oil.

In work [7] written by Gudzenko M, Vasyliv V et al. a twin-screw extruder was investigated to simplify the processing of oilseeds. The influence of the geometric parameters of the screw on oil release was studied. The rational parameters were determined using theoretical calculations and experiments. The dependence of the oil yield on the geometry of the screw was confirmed. The effect of the decline of the free volume of the screw on the efficiency and productivity of the extruder-press was revealed.

The research outlined in reference [8] and authored by Gudzenko M, Vasyliv V et al. delves into the issue of low oil yield in the process of sunflower oil extraction. The essential parameters for enhancing the twin-screw extrusion presses' design to augment oil yield were thoroughly investigated. The study introduces empirical methods and new working components, specifically cylindrical-conical nozzles, leading to a notable increase in oil yield up to 3.1%.

In [9] written by Alabi K, Busari R, Joel O a screw press with a variable width of a cone-shaped shaft was developed to increase the oil production from the palm tree fruits. The machine demonstrated superior performance when operated at 130°C, with a heating duration of 25 min, and with a rotation speed of 60 rpm. Under these conditions, it achieved an oil yield of 83.72%, an extraction efficiency of 97.73%, and an extraction loss of 2.37%.

In the paper [10], the authors Mursalykova M, Kakimov M et al. focused on the simulation of the oil extraction process using a screw press in small enterprises for Safflower production. The article addresses the challenge of extracting the liquid phase from dispersed material. Employing mathematical modeling, the study identifies the optimal parameters for oil extraction, which include a screw rotation speed of 6.2 rad/s. and diaphragm gap of 0.1 mm.

The paper [11] authored by Iskakov B, Kakimov M et al. investigates the improvement of the purification of Safflower oil using biologically based secondary processing products. It has been established that the use of flax fiber for filtering improves the quality of the oil, increasing the content of useful substances and antioxidant components. Optimum centrifugation conditions for increasing the efficiency of Safflower oil processing are proposed. The research [12] written by Zikri A, Aswan A et al. is aimed at maximizing oil yield when obtaining coconut oil from copra using a screw press machine. Factors such as temperature and screw speed are analyzed. Energy intensity and extraction efficiency during the coconut oil production process are also evaluated. The paper [13] authored by Muhammad Afriza Zaini T, Ali S is aimed at analyzing the effect of screw press pressure on palm oil production in the company. It has been found that the correct pressure is important for the quality and quantity of oil obtained.

In the investigation [14] authored by Mansor MN, Salleh SM et al., the focus is on assessing the screw press technology utilized in palm oil production. Its objective is to assess the durability of both twin and single screw designs, aiming to determine which design offers the maximum screw life. The article [15] written by Charan G, Krishna AR et al. concerns the creation, assembly, and testing of press for oil extraction from sesame, coconut, groundnut, and mustard seeds. The press uses a screw mechanism without the use of chemical solvents, ensuring a safe and efficient process. The applied electric motor with a power of 1 hp, the pressure analysis of the propeller confirms the safety and durability of the device. The study [16] authored by Sarbeni S and Saputra A applies the FMEA method to identify breakdowns and prioritize repairs. Using this method, the authors discovered that the special bearing component required immediate repair.

The research [17] written by Sakdasri W and Silangam P explores in detail the use of screw presses for extracting oil from black cumin seeds. Conditions of oil extraction were optimized by considering parameters such as feed rate, temperature, and humidity. The maximum oil yield (31.67 wt%) was achieved at parameters of 45 g/min, 70°C and 6 wt% moisture. Under optimal conditions (50–54 g/min, 15–18wt%, and 55–60°C), a yield of 22 wt% oil and a thymoquinone content of 10 mg/ml were achieved.

Considering the process of extracting oil in a screw press [18], Bako T, Obetta SE and Umogbai VI developed a theory for the mathematical description of this phenomenon. Using experimental data, a model was determined, which was confirmed using regression analysis. The reliability of the model is emphasized by high indicators of correlation, determination, etc. It is important to note that this model effectively predicts results on commercial presses, which opens up the possibility of collecting press performance data without costly experiments. The analysis presented in [19] and performed by Wang S, Wang J et al. examines the effect of roasting and extraction methods on the quality of rapeseed and linseed oils. The results indicate a great influence of different methods on yield, sensory characteristics, composition of oils, and physicochemical properties. The choice of extraction method is important for the production of oils in large volumes.

The paper [20] written by Bogaert L, Mathieu H et al. studied the mechanical expression of oils in a screw press using a pilot press. It was found that increasing the speed of rotation of the screw improves the productivity of the press, shortens the time of passage, and reduces the extraction of oil. Data fixation made it possible to identify different functional sections of the press. The research outlined in reference [21] authored by Kabutey A., Herák D., and Mizera Č. evaluated oil yields from different types of seeds, including hemp, sesame, flax, pumpkin, madder, and cumin. Sesame was found to have the highest oil yield (30.60%), while cumin had the lowest (3.46%). The analysis of the quality of the obtained oils revealed certain aspects that require attention, especially in pumpkin oil. Potential for further research includes consideration of temperature impact, efficiency of oil recovery, and other processing aspects. The work [22] written by Kabutey A, Herák D and Mizera Č determined the optimal conditions for obtaining oil from carded sunflower seeds. The maximum yield of oil (48.869%) was achieved without preheating on the fifth pressing. The quality of the obtained oils meets the standards, and spectral analyses confirm the low content of pigments. Repeated pressing helps extract residual oil from the cake. In the article [23] authored by Wang S, Wang J et al. the development and modeling of an improved screw press for extracting oil from plants are described. The research aims to examine the press design and investigate the stress-deformed state of the screw under difficult conditions. The findings of this study have the potential to enhance the longevity, durability, and reliability of screw presses.

The use of the latest smart technologies in industry allows improving and optimizing production processes. A great example of this is using an Arduino Mega controller to control the oil extraction process. The importance of correct management and control of parameters such as speed and temperature becomes critical to achieve needed results. Arduino Mega controller as an integrated control system is defined as a main element in the smart oil ex-

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traction process, ensuring precision and stability in the regulation of several parameters. In particular, the extraction speed can be dynamically adjusted to adapt to different production conditions, ensuring high efficiency of oil extraction. Temperature control is another important function, where the controller monitors the temperature of the shaft and the motor. This avoids overheating, which can affect oil quality and increase energy consumption. Using the Arduino Mega it becomes possible to implement automated functions, such as a cooling system that starts when a certain temperature level is reached, or automatic heating control to maintain a constant temperature during the extraction process. The ability to monitor various parameters such as shaft speed, motor, and shaft temperature makes this system not only a control tool but also a data collection and analysis tool. This contributes to the optimization of the entire process of oil extraction, ensuring high product quality and rational use of resources.

The project [24] developed by Badigannavar R, Kavadamatti A and Kulkarni G deals with the automation of fan speed control depending on the ambient temperature using Arduino. The system obtains temperature information from the sensor and modifies the speed based on the temperature settings specified by the operator. Information about temperature and speed is displayed on the LCD display. If the ambient temperature is higher than the set temperature, the fan will turn on, and vice versa.

The paper [25] authored by Li Y, Jin Z tackles the challenges associated with the traditional screw extruder control system, characterized by low-quality stability, increased manual workload, and a limited level of mechanical automation due to manual feed rate control. The article proposes the implementation of an intelligent screw extruder control system employing a fuzzy control algorithm. Utilizing pressure and temperature data from the oil press for detection, the fuzzy control algorithm mimics expert experience to autonomously regulate the speed of the motor. This mechanism is centralized around a PLC that is used as the main controller, while MATLAB is employed for simulation and testing. Based on the simulation and testing outcomes, the smart screw extruder exhibits enhanced control effectiveness and overall stability using the fuzzy control algorithm. The study [26] carried out by Muliak N, Zdobytskyi A et al. focuses on resolving design problems and enhancing algorithm accuracy in various complex systems. Multiple algorithms were compared based on analytical data and the optimal one was suggested for the design of MEMS.

## 2. MATERIALS AND METHODS

This section considers the following issues: initial design and operational peculiarities of the screw press for extracting oil from different oil-containing plants; main types of seeds and kernels that can be processed and basic technical characteristics of the press; major tasks set for developing the control system intended for automation of the oil extraction process; general algorithm of the control system operation; experimental implementation of the developed control system and modernized screw press.

### 2.1. Initial prototype of the screw press for oil extraction

The general design of the small household screw press LiangTai LTP200 is presented in Fig. 1 [27]. It is intended for cold and hot pressing of different seeds and extracting oil at the productivity range of 2…5 kg/h depending on the working regimes and type of the oil-containing material. The overall dimensions of the press are 410×160×305 mm and the mass is about 9 kg. The nominal power consumption does not exceed 650 W at the supplied alternating voltage of 220 V of the 50 Hz frequency.

The hopper 1 is filled with the seeds to be processed. The lower discharging cylindrical hole (port) of the hopper is mounted in the conveying chamber 6. The latter is connected with the pressing chamber 7, in which the oil extraction and cake formation processes are conducted. The pipe 8 is used for discharging the cake from the pressing chamber 7 and supplying it to some boxes, bags or packages. The extracted oil is fed to the tank (bowl) 9 and is preliminary filtered with the help of the sieve 10.

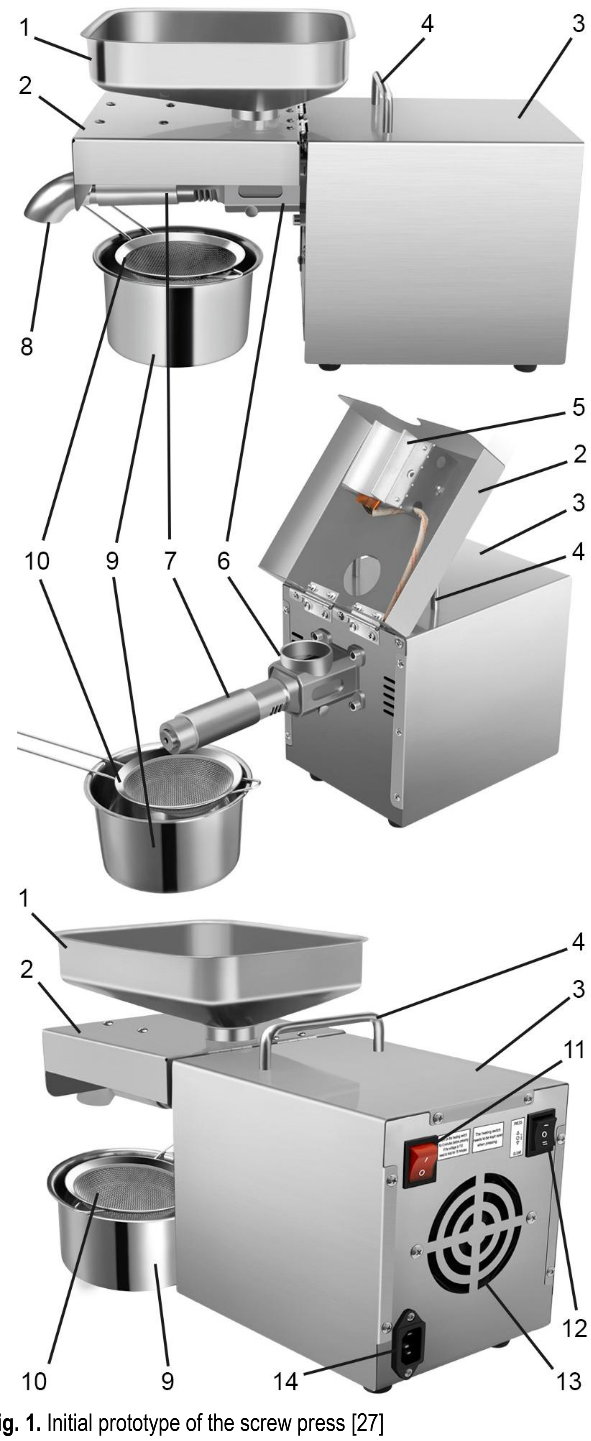

**Fig. 1.** Initial prototype of the screw press [27]

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The flat (hinged) frame 2 is joined with the press body 3. The electric heating element (heater) 5 is fixed on the frame 5, which squeezes it up against the cylindrical surface of the pressing chamber 7. The latter is to be preheated before the working regime starts in order to increase the efficiency of the oil extraction process. The corresponding preheating temperature depends on the type of the seeds to be pressed. The press body 3 is equipped with the additional handle 4 that allows for easy carrying (transportation) of the machine. The general power supply of the screw press is provided from the 220 V (50 Hz) electric network through the connector 14. The two-position switch 11 energizes the heater 5 before the start of the oil extraction process during the technologically prescribed time period. After this, the operator chooses the first position (position "I") on the switch 12 to start the pressing process. If there is a need to stop the machine, the position "0" should be chosen on the switch 12. In the case when the screw cleaning operation should be performed, the operator must change the switch 12 position to "II" providing the reversive rotation of the driving motor shaft. The ventilation openings (holes) 13 are used for the forced supply of the cooling air inside the press body 3, in which the machine drive and control system is installed.

Considering the existent design of the press, the present paper is aimed at developing the control system allowing for automation of the oil extraction process for different seeds and kernels.

### 2.2. The main types of seeds and kernels that can be processed

The considered household screw press LiangTai LTP200 is intended for extracting oil from the following seeds and kernels: peanut, sesame, rapeseed, sunflower, almond, flaxseed, mustard, walnut, perilla, soybean, hemp, etc. (see Fig. 2 [27]). According to the manufacturer's documentation [27], the approximate oil extraction rate and material processing productivity of the screw press for some types of seeds are presented in Tab. 1.


**Fig. 2.** Main types of seeds to be pressed [27]

All the mentioned seeds and kernels require different technological conditions to be provided in order to maximize the qualitative and quantitative parameters of the extracted oil. Therefore, there is a need to adjust the working regimes of the press, particularly, the rotational frequency of the screw and the temperature of the pressing chamber. In addition, the customer may need to set the required mass of the oil to be extracted. All these tasks are to be solved by the control system, which will be developed in the following sections of this research.

**Tab. 1.** Performance characteristics of the press LiangTai LTP200 [27]

| Seed (kernel) type | Oil extraction rate [%] | Material processing productivity [kg/h] |
|---|---|---|
| Peanut | 39...45 | 2.27...3.63 |
| Rapeseed | 30...39 | 3.63...4.54 |
| Sunflower | 41...52 | 3.18...4.54 |
| White sesame | 39...52 | 3.63...4.54 |
| Black sesame | 44...53 | 3.63...4.54 |
| Walnut | 58...68 | 2.27...3.18 |
| Almond | 48...57 | 2.27...3.18 |
| Flaxseed | 31...39 | 3.63...4.54 |
| Perilla | 30...42 | 3.63...4.54 |

### 2.3. Major tasks set for developing the control system

Considering the necessity of extracting oil from different types of seeds mentioned above, different technological parameters are to be provided by the control system. The following parameters are monitored during the press operation: rotational frequency of the screw; temperatures of the pressing chamber, extracted oil, and driving electric motor; mass of the oil; consumption current and voltage of the motor. Based on the technological requirements and recommendations, the nominal temperature of the pressing chamber and the screw rotational frequency should depend on the type of the seeds to be pressed. The optimal operational parameters of the screw press allow for providing the best qualitative and quantitative parameters of the oil extracted.

Taking into account the conclusions drawn above, the enhanced control system of the considered screw press should provide the possibility of regulating the screw rotational frequency and the temperature of the pressing chamber. In addition, the electric motor temperature and consumption current must be limited in order to prevent drive damage (breakdown). The latter can occur in the case when the screw is jammed (wedged). Depending on the oil mass required by the consumer, the control system must stop the pressing process when the necessary mass is reached. The mentioned temperatures can be limited by means of applying additional electric coolers with adjustable rotational frequencies depending on the temperature value.

### 2.4. General algorithm of the control system operation

The general algorithm of the control system operation can be described by the block diagram (flow chart) shown in Fig. 3. After supplying the electric power to the control system, the corresponding sensors register the temperature $t_{pr.ch.}$ of the pressing chamber, the mass $m_{oil}$ of the oil tank (bowl), the temperature $t_{oil}$ of oil (or air) inside the tank, the temperature $t_{mot.}$ of the electric motor, and the voltage and current consumed by the enhanced control system and electric drive.

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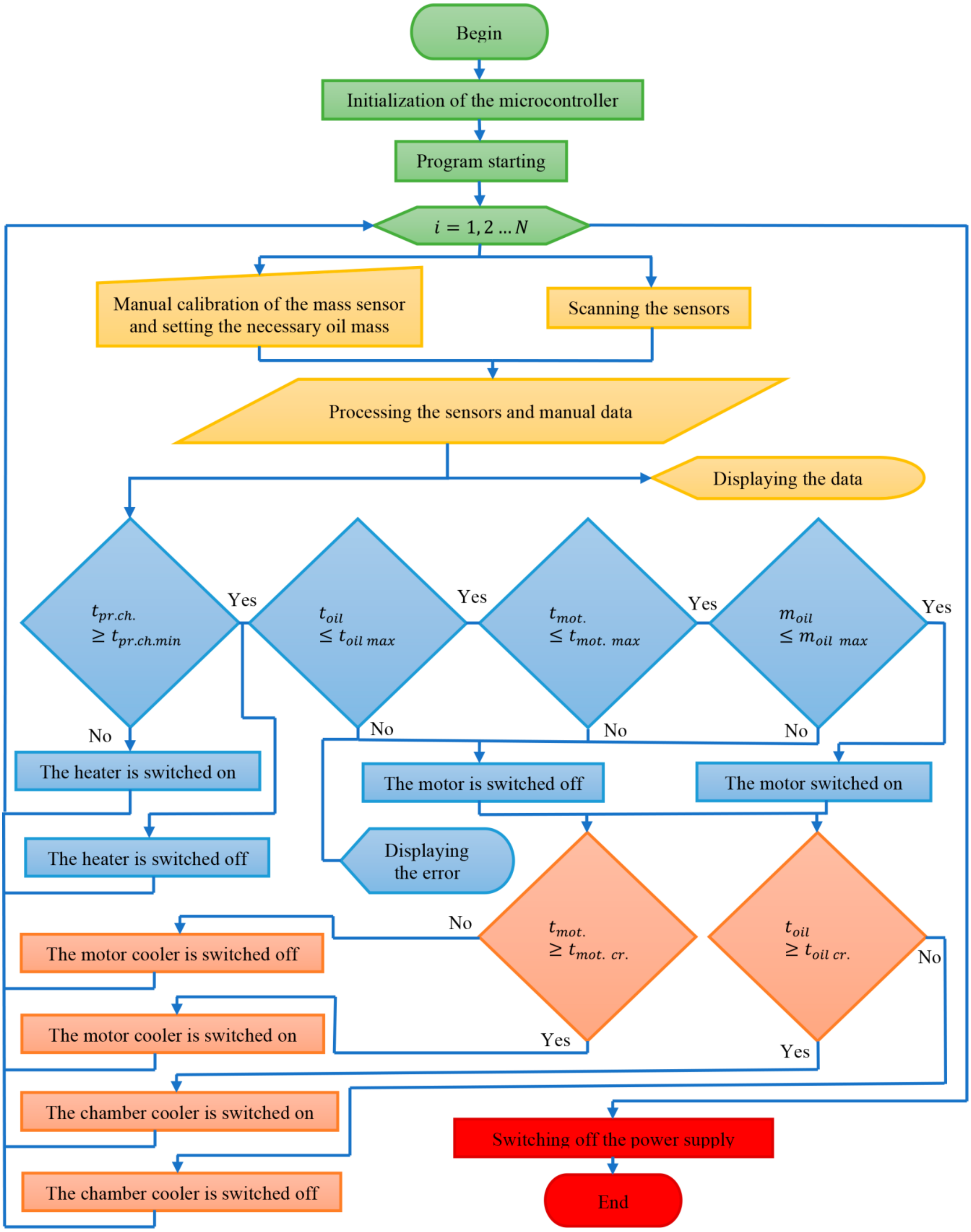

**Fig. 3.** Simplified block diagram (flow chart) describing the general algorithm of the control system operation

At the beginning, the mass sensor should be calibrated and reset to zero. Then, the consumer must choose the required mass $m_{oil\ max}$ of the oil to be extracted. By default, the system is programmed to press 100 g of oil. After this, the operator pushes the „START" button and the heater begins to preheat the pressing chamber to the temperature $t_{pr.ch.min}$ prescribed by the technological requirements and depending on the type of seeds to be processed. This temperature is registered by the corresponding sensor. At the moment when the temperature reaches the required value, the control system switches the heater off and starts the electric motor at its nominal (maximal) parameters. In this case, the rotational frequencies of the motor shaft and pressing screw take their maximal values, and the oil extraction process is conducted. When the motor temperature reaches the critical value $t_{mot.\ cr.}$ prescribed by the manufacturer, the corresponding cooler is to be switched on to limit the temperature growth. The additional sensor is used for registering the temperature $t_{oil}$ of the oil being extracted. When this temperature grows over a technologically prescribed value $t_{oil\ cr.}$, the corresponding cooler starts working at the specified frequency (cooling intensity). If the oil temperature continues growing, the cooling intensity is to be increased and the screw rotational frequency is to be reduced. This allows for restricting the oil overheating, which negatively influences its qualitative characteristics. When the temperatures of the oil or motor reach the maximal allowable values $t_{oil\ max}$ or $t_{mot.\ max}$, respectively, the control system stops the pressing process. The same algorithms are performed in the case when the mass sensor registers the oil mass $m_{oil\ max}$ prescribed by the consumer or when the oil mass is not changing during the specified time period. The latter means that there are no seeds to be pressed or that the pressing chamber is chocked (stuffed) up with the cake. The stopping process is accompanied by the audible alarm and the error description shown on the display. After each stop, the control system provides the reversive motion of the screw in order to clean the pressing chamber. Additionally, the screw reversive rotation can be ensured by means of pushing the „REVERSE" button. At any time moment, particularly, when an emergency situation occurs, the corresponding „STOP" button should be pressed by the operator (consumer). The starting and stopping processes are continuously (smoothly) conducted according to the programmed algorithm due to the use of the frequency converter (changer). The latter additionally provides the possibility of limiting the maximal consumption current of the electric motor, as well as controlling the rotational frequencies of the motor shaft at different operational conditions (direct and reversive rotation, oil mass $m_{oil}$ and temperature $t_{oil}$, motor temperature $t_{mot.}$, pressing chamber temperature $t_{pr.ch.}$, etc.).

### 2.5. Development of the schematic diagram of the enhanced control system implemented in the press drive

The principle of operation and connection of the control and diagnostic elements in the press control circuit (see Fig. 4) are based on the Arduino Mega microprocessor (U1). The proposed principal scheme involves the use of both digital and analog ports, as well as PWM ports. The status of the temperature sensors (DS18B20 sensors (U4-U6)) and weight module (HX711 (U8)) is displayed on the LCD screen 2004 (U3), which is connected via the I2C bus. The DS18B20 sensors are connected to the analog outputs via pull-up resistors. The possible connection errors or sensor malfunctions are displayed on the LCD. The HX711 weight module is connected to the digital pin. To measure the motor speed, there is used the YS-27 Hall sensor (U5), which is connected to a digital pin that operates in an interrupted mode.

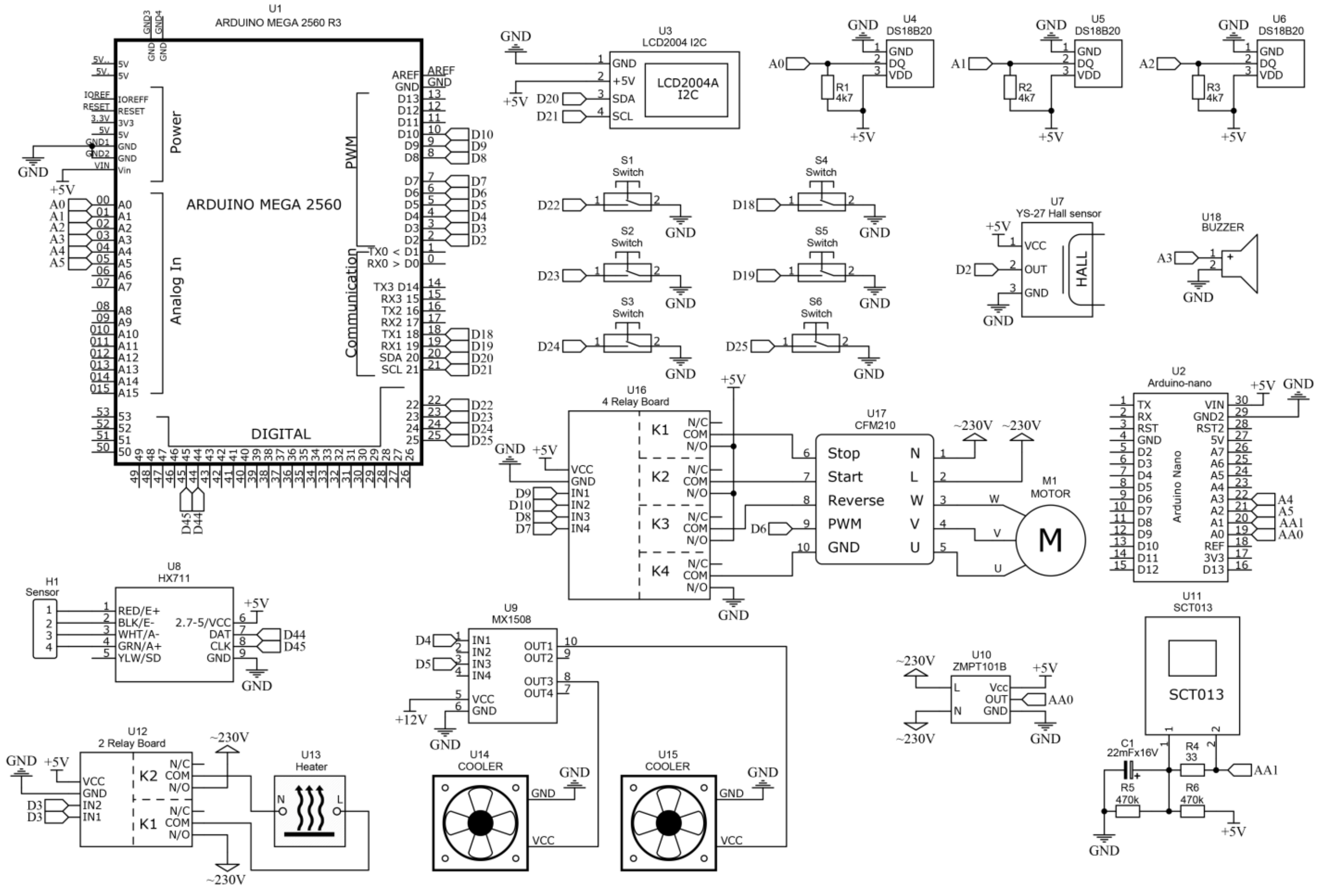


**Fig. 4.** Schematic diagram of the enhanced control system implemented in the press drive

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To display the current and voltage parameters, there are used the ZMPT101B (U10) and SCT013 (U11) sensors, which are connected to the Arduino Nano board (U2). The use of the Arduino Nano microcontroller is due to the fact that the processing of voltage and current sensors takes a significant amount of time, so for the main algorithm to work steadily with interruptions, there is a need to use another microcontroller that will be responsible only for polling these sensors. The fans (coolers) (U14 and U15) are controlled by the MX1508 two-channel motor driver module (U9). The speed of the fans is controlled by a PWM signal.

The pressing chamber is heated by the heater U13. The heater is controlled by the relay module U12, which receives control signals from the Arduino Mega. The motor speed is controlled by the PWM signal, which is supplied directly to the CFM210 frequency converter (U17), and all other functions are controlled through the relay module (U16). The use of the relay module is due to the fact that there is simulated manual control of the converter, which provides the flexibility to choose frequency, rather than prescribe a different algorithm for each one. The asynchronous motor is connected directly to the frequency converter, which allows for adjusting its speed without significant power loss. A buzzer (U18) is provided to signal an emergency or the end of the press operation. The start, stop, and reverse of the motor are controlled by buttons with normally open contacts S1-S3, and the weight parameters are controlled by buttons S4-S6.

## 2.6. Experimental implementation of the control system

The experimental prototype of the modernized screw press equipped with the developed control system is presented in Fig. 5. The seeds are to be charged into the hopper 1, which is installed in the conveying chamber 2. During the machine operation, the seeds are conveyed by the screw 3 to the pressing chamber 4, where they are destructed and the oil is extracted. The oil flows out of the pressing chamber 4 through the holes at its bottom part to the tank (bowl) 5. The cake being formed during the pressing process is discharged through the pipe 6 to the tank (bowl) 7. The rotation of the screw 3 is generated by the two-stage cylindrical gearbox 8 driven by the asynchronous electric motor 9.

Considering the proposed control system, the latter allows for preheating the pressing chamber before the machine operation starts. This allows for improving the qualitative and quantitative parameters of the oil extracted. The corresponding heater 10 is mounted on the sprung arm (bracket) 11, which can change its angular position relative to the press body due to its hinged installation. On the other hand, when the temperature of the extracted oil is larger than the technologically specified value, the additional cooler (fan) 12 is to be activated in order to restrict the oil overheating. The latter can cause the reduction of the oil's qualitative parameters. The temperatures of the extracted oil, pressing chamber 4, and electric motor 9 are monitored by the corresponding sensors 13, 14, and 15. If at least one sensor shows a temperature that is larger than the permissible value, the control system stops the pressing process. If the temperature of the oil or electric motor reaches the specified critical value, the corresponding coolers (fans) 12 and 16 are activated to restrict further growth of the temperature. The mass sensor 17 is applied to monitor the mass of the oil being extracted. The sensor is mounted on the press body by one end, while the other end holds (supports) the plate 18, on which the oil tank (bowl) 5 is placed. Before starting the pressing process, the operator (consumer) prescribes the required mass of oil to be extracted. When the mass sensor 17 registers the prescribed value, the control system stops the screw rotation. In the case when the oil mass is not changing during the specified time period, the control system stops the pressing process, because there can be no seeds to be pressed or the pressing chamber 4 can be choked (stuffed) up with the cake. Each stopping process is accompanied by the reversive rotation of the screw 3 aimed at cleaning the pressing chamber 4 and by the audible alarm and error description shown on the display 19.

The control system additionally contains the frequency converter 20 intended for regulating the rotational frequency of the electric motor shaft and for providing the programmed algorithms for continuous starting and stopping of the press drive. One of the main components of the control system is the Arduino Mega microcontroller 21 energized by the power supply unit 22. On the top plate of the press body, there are installed the control buttons and display 19. The green button 23 is the „START" one, which switches on the pressing process. The blue button 24 is used to provide the reversive rotation of the screw 3. The red button 25 is the „STOP" one, which switches off the power supply to the drive. The other three buttons 26, 27, 28 are used for calibrating (resetting to zero) of the oil mass sensor and for manual increasing and decreasing of the required mass of oil to be extracted.

The display 19 continuously shows the instantaneous oil temperature ("Oil:"), temperature of the electric motor ("M:"), mass of the oil located in the bowl ("IMV:"), and manually prescribed oil mass ("Mass:"). The corresponding errors show that the mass of the oil located in the bowl is larger than the prescribed mass ("MASS ERR"); the oil temperature is larger than the technologically permissible value ("OIL ERR"); the mass of the extracted oil is not changing for a specified time period ("EMPTY ERR"); the temperature of the electric motor is larger than the one prescribed by the manufacturer ("MOTOR ERR").

Additionally, the control system allows for registering the instantaneous values of the motor shaft rotational frequency using the Hall-effect sensor 29, and the consumption current and voltage of the whole control system and electric drive with the help of the amperemeter 30 and voltmeter 31. The frequency controller allows for limiting the maximal current supplied to the electric motor in order to provide its reliable and durable operation. Further improvements can be focused on applying additional sound and visual sensors for analyzing specific operational conditions.

The sensors DS18B20 used for measuring the temperature of the pressing chamber, electric motor, and extracted oil are pre-calibrated using the pull-up resistors and are connected to the analog outputs of the Arduino Mega microcontroller. According to the manufacturer's documentation, the sensors are characterized by the working temperatures of –55…+125°C and the accuracy of ±0.5°C (within the temperature range of –10…+85°C). Considering the nominal temperatures of the screw press operation (15…85°C), the error of the experimental measurements does not exceed 3.5%. The mass sensor in the form of the strain gauge is used for converting the strain value of the aluminum beam into the electric signal. Then the signal is processed by the HX711 weight module connected to the digital pin of the Arduino Mega microcontroller. According to the manufacturer's documentation, the strain gauge and the weight module can detect the mass within the range of 0…1 kg at the total accuracy of 0.2%. Therefore, the maximal mass error of the extracted oil does not exceed 2 g. The duration of the pressing process is measured using the Arduino built-in functions that return the number of milliseconds since the board started running (the heater started heating the chamber).

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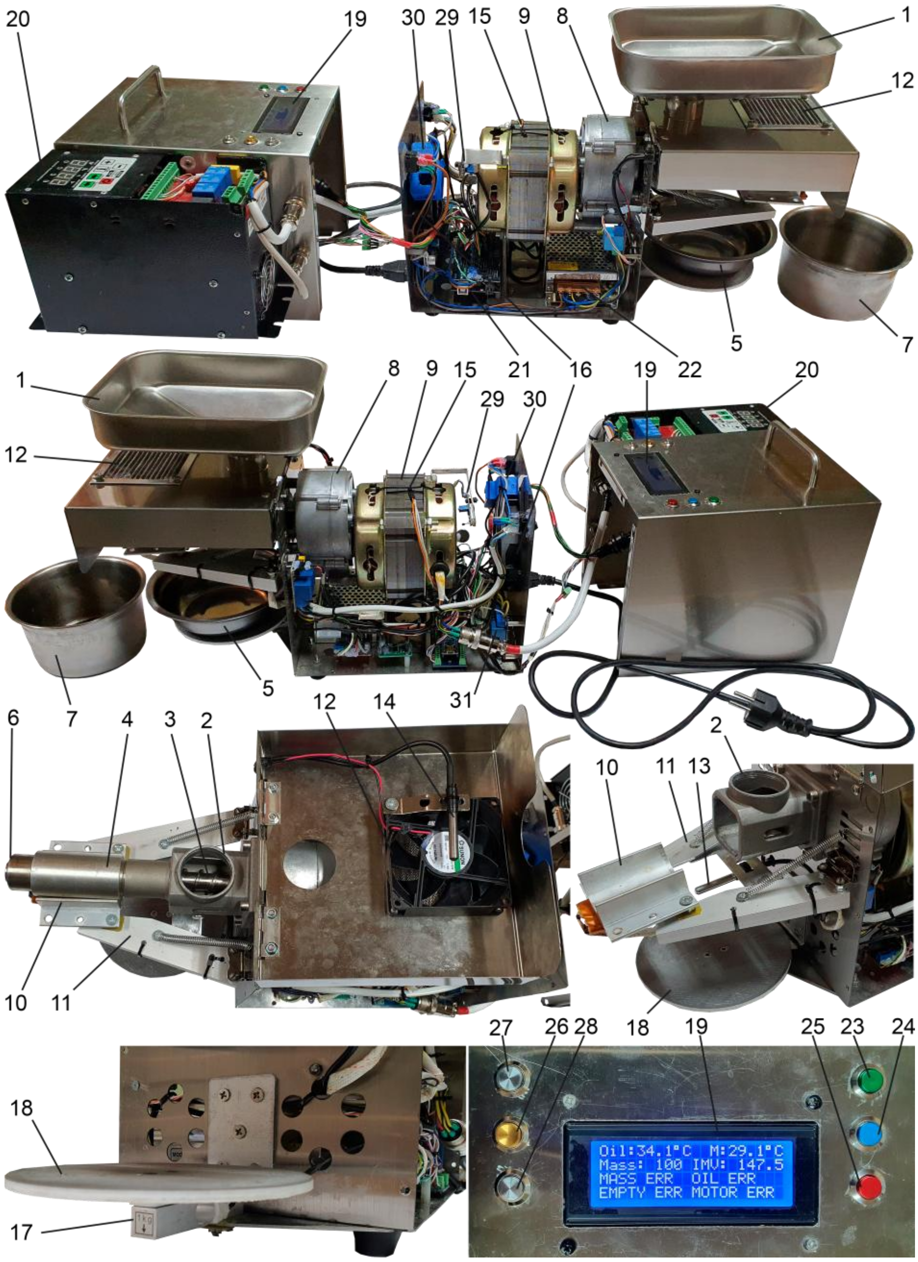


**Fig. 5.** Basic components of the experimental control system of the modernized screw press

## 3. RESULTS AND DISCUSSION

This section is devoted to experimental investigations of the developed control system and modernized machine operation during the pressing process of the sunflower, peanut, almond seeds, and walnut kernels. The following parameters are considered: temperature of the pressing chamber; temperature and mass of the oil being extracted; temperature of the electric motor. The minimal temperature of the working chamber for the drive to be powered is set to $t_{pr.ch.min} = 42°\text{C}$. The critical temperature of the oil for the corresponding cooler (fan) to be activated is the following $t_{oil\ cr.} = 45°\text{C}$. The maximal permissible temperature of the oil for the press to be stopped is equal to $t_{oil\ max} = 65°\text{C}$. The critical temperature of the motor for the corresponding cooler (fan) to be activated is the following $t_{mot.\ cr.} = 70°\text{C}$. The maximal permissible temperature of the motor for the press to be stopped is equal to $t_{mot.\ max} = 75°\text{C}$. The initial temperature of all parts of the press is approximately equal to the temperature inside the laboratory room: $t_{init.} \approx 20°\text{C}$.

### 3.1. Analyzing the changes in the temperature of the pressing chamber

The temperature of the pressing chamber significantly influences the productivity of the oil extraction process and the qualitative parameters of the oil [6, 9, 17]. This fact causes the necessity of regulating the corresponding temperature during the whole pressing process. After supplying power to the control system, the latter starts scanning the sensors and processing the obtained data. Then, the operator (consumer) sets the necessary mass of the oil to be extracted and pushes the "START" button. If the chamber temperature is less than the technologically prescribed value, the electric motor is not powered and the pressing process does not start. According to the time dependence of the tempera-

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ture of the pressing chamber (Fig. 6), its initial value is almost equal to the temperature inside the laboratory room (20°C). Therefore, the heater is switched on and the temperature rises to about 42°C for approximately three minutes (170…190 s).

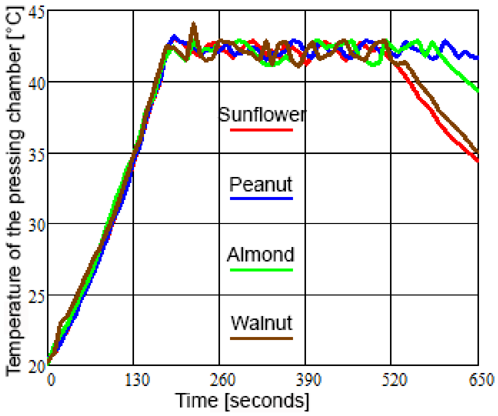


**Fig. 6.** Dependence of changes in the temperature of the pressing chamber during the pressing of different seeds

After the chamber temperature reaches the minimal value, the electric motor is switched on and the oil extraction process starts. During the seeds (kernels) pressing, the temperature inside the chamber rises. When the temperature of the extracted oil reaches the value of 45°C, the corresponding cooler is switched on. The cooler allows for limiting the temperature of the pressing chamber within the range of 42…44°C during the whole oil extraction process. The reduction of the chamber temperature after 500 s means that the process has been finished and the required mass of the extracted oil has been obtained. After approximately 11 min (650 s), when the latest peanut pressing process ends, the lowest temperature of the chamber of approximately 34°C is observed for the case of the sunflower pressing.

### 3.2. Studying the oil temperature changes

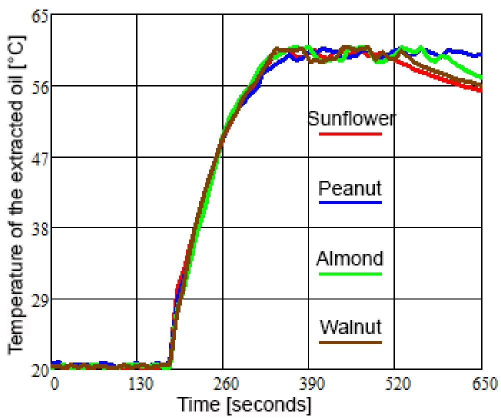


**Fig. 7.** Dependence of changes in the temperature of the extracted oil during the pressing of different seeds

The temperature of the extracted oil significantly affects its qualitative and taste characteristics. Considering the changes in the temperature of the extracted oil (Fig. 7), it remains unchanged for approximately three minutes (170…190 s), when the pressing chamber preheating process is performed. After this time, the pressing process starts and the oil temperature sensor registers the corresponding changes. It takes about 2.5…3 min for the oil to reach the nominal temperature of approximately 60°C, which remains almost unchanged during the whole pressing process. When the required mass of the oil is extracted, the pressing process stops and the oil starts cooling down. After approximately 11 min (650 s), when the latest peanut pressing process ends, the lowest temperature of the extracted oil of approximately 55°C is observed for the case of the sunflower pressing.

### 3.3. Monitoring the motor temperature

The electric motor temperature should be restricted due to the manufacturer's recommendations. During the pressing process, when the frequency converter is continuously changing the rotational speed of the pressing screw in accordance with the programmed algorithm, the temperature of the electric motor significantly increases. In order to restrict the motor overheating, the corresponding cooler is switched on, when the motor temperature rises over 70°C. As can be seen in Fig. 8, during approximately 3 min (170…190 s), the motor temperature is almost equal to the temperature inside the laboratory room (20°C). Then the temperature rises to about 70°C and changes within the range of 69...71°C till the end of the pressing process. After approximately 11 min (650 s), when the latest peanut pressing process ends, the lowest temperature of the electric motor of approximately 60°C is observed for the case of the sunflower pressing.

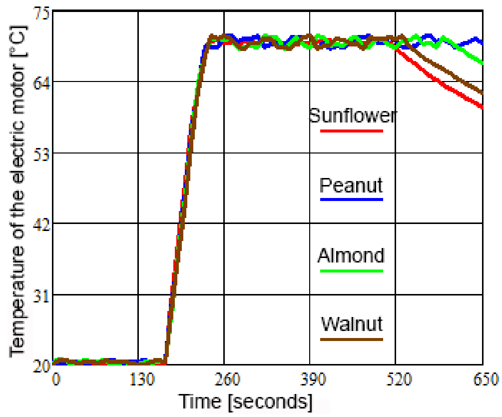


**Fig. 8.** Dependence of changes in the temperature of the electric motor during the pressing of different seeds

### 3.4. Monitoring the change in the oil mass

As has been already mentioned, after switching on the power supply, the operator calibrates the corresponding sensor (resets it to zero) and chooses the required mass of oil to be extracted. By default, the corresponding mass is programmed to be equal to 100 g. Considering the experimental data presented in Fig. 9, the extracted oil mass takes zero values during the pressing chamber preheating process (about 3 min). Then, the oil extraction process starts and the mass sensor monitors the corresponding changes.

While pressing the sunflower seeds, the nominal mass of the extracted oil was obtained within approximately 490 s from the moment of switching on the power supply. The corresponding durations of the pressing processes for the peanut, almond, and walnut kernels are the following: 650 s, 590 s, and 530 s. Herewith, it should be noted that the separate pressing process lasts for about 300 s (sunflower seeds), 340 s (walnut kernels), 400 s (almond kernels), and 460 s (peanut kernels).

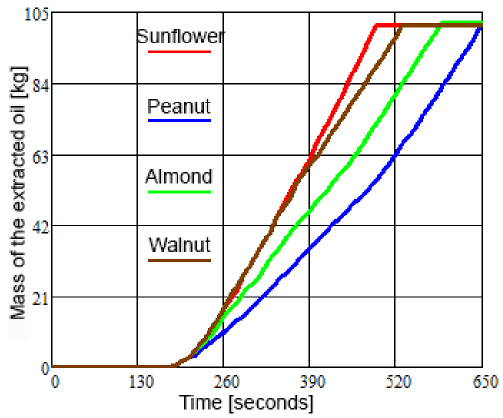


**Fig. 9.** Dependence of changes in the mass of the extracted oil obtained during the pressing of different seeds

### 3.5. Discussion

Based on a thorough analysis of various investigations on the processes of oil extraction from different seeds and kernels of oil-containing plants, particularly [1–3], the present research is focused on developing and experimental testing of the control system allowing for regulating various operational parameters of the pressing process. While performing further investigations on the considered subject, a comprehensive analysis of the influence of these parameters on the quantitative and qualitative characteristics of the extracted oil is to be conducted.

Considering the results shown in Figs. 6–9, the control system is programmed in such a way that the oil extraction process does not start until the temperature of the pressing chamber reaches the prescribed temperature. This regulation has been implemented on the basis of numerous research results, particularly [5, 6, 19, 20, 22], which substantiate the fact that the temperature of the pressing chamber significantly influences the productivity of the oil extraction process and the qualitative parameters of the oil. On the other hand, the temperature of the extracted oil also affects its qualitative and taste characteristics [6, 19, 22]. Therefore, while implementing the corresponding control algorithms of the cooler (fan) operation, the general ideas presented in [24] have been considered.

**Tab. 2.** Experimental data defining productivity of the pressing process

| Seed type | Oil mass [g] | Pressing duration [s] | Oil extraction productivity [kg/h] |
|---|---|---|---|
| Peanut | 100 | 460 | 0.78 |
| Sunflower | 100 | 300 | 1.2 |
| Walnut | 100 | 340 | 1.06 |
| Almond | 100 | 400 | 0.9 |

Obviously, the maximal working temperature of any electric motor should be limited. The nominal temperature is usually prescribed by the manufacturer. In order to restrict the drive damage (breakdown) due to motor overheating, the additional cooler (fan) is used. The latter allows for maintaining the almost constant temperature of the electric motor during the pressing process. Some ideas for implementing the corresponding control algorithms have been chosen from [25, 26].

The last parameter that has been monitored during the crew press operation is the mass of the extracted oil, which was initially set by the operator (consumer). This parameter allows for approximately determining the productivity of the pressing process for different seeds and kernels. In the current research, the main attention has been focused on four products: sunflower seeds; peanut, almond, and walnut kernels. The nominal oil mass of 100 g has been chosen for conducting the experiments. The pressing processes, which do not take into account the preheating duration, last for about 300 s (sunflower seeds), 340 s (walnut kernels), 400 s (almond kernels), and 460 s (peanut kernels). These data allow for determining the productivity of the considered screw press for the mentioned seeds and kernels. Considering the experimentally obtained results shown in Tab. 2, the conclusions about their satisfactory agreement with the manufacturer's technical documentation presented in [27] can be drawn.

## 4. CONCLUSIONS

The paper considers the possibilities of automation of the oil extraction process performed by means of the small household screw press LiangTai LTP200. The latter is intended for extracting oil from the following seeds and kernels: peanut, sesame, rapeseed, sunflower, almond, flaxseed, mustard, walnut, perilla, soybean, hemp, etc. Considering the basic design parameters of the press and the main technological requirements set to the oil extraction process, the corresponding control algorithm is developed (see Fig. 3). The proposed control system provides the possibility of regulating the screw rotational frequency and the temperature of the pressing chamber. In addition, the electric motor temperature and consumption current are limited in order to prevent drive damage (breakdown). Depending on the oil mass required by the consumer, the control system stops the pressing process when the necessary mass is reached. The mentioned temperatures are limited by means of applying additional electric coolers with adjustable rotational frequencies depending on the temperature value.

Based on the developed algorithm, the corresponding control system is implemented and experimentally tested. The obtained results show that the pressing chamber preheating process lasts for about 3 min (170…190 s). The maximal temperature of the chamber does not exceed 44°C due to the application additional cooler (fan). Herewith, the temperature of the extracted oil does not rise over 61°C. In order to restrict the electric motor overheating, the corresponding cooler is switched on, when the motor temperature rises over 70°C. Therefore, this temperature changes within the range of 69...71°C during the whole pressing process. The nominal oil mass of 100 g has been chosen for conducting the experiments. The pressing processes, which do not take into account the preheating duration, last for about 300 s (sunflower seeds), 340 s (walnut kernels), 400 s (almond kernels), and 460 s (peanut kernels). Therefore, the corresponding oil extraction productivity of the considered press is the following: 1.2 kg/h, 1.06 kg/h, 0.9 kg/h, and 0.78 kg/h.

While performing further investigations on the considered subject, a comprehensive analysis of the influence of the controllable temperature parameters on the quantitative and qualitative characteristics of the extracted oil is to be conducted.

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**REFERENCES**

1. Choton S, Gupta N, Bandral JD, Anjum N, Choudary A. Extrusion technology and its application in food processing: A review. Pharma Innov. 2020;9(2):162-168. https://doi.org/10.22271/tpi.2020.v9.i2d.4367
2. Nde DB, Anuanwen CF. Optimization methods for the extraction of vegetable oils: A review. Processes. 2020;8. https://doi.org/10.3390/pr8020209
3. Frangipane MT, Cecchini M, Monarca D, Massantini R. Effects of Filtration Processes on the Quality of Extra-Virgin Olive Oil-Literature Update. Foods. 2023;12. https://doi.org/10.3390/foods12152918
4. Guerrini L, Breschi C, Zanoni B, Calamai L, Angeloni G, Masella P, et al. Filtration Scheduling: Quality Changes in Freshly Produced Virgin Olive Oil. Foods. 2020;9(8). https://doi.org/10.3390/foods9081067
5. García-González A, Velasco J, Velasco L, Ruiz-Méndez MV. Attempts of physical refining of sterol-rich sunflower press oil to obtain minimally processed edible oil. Foods. 2021;10(8). https://doi.org/10.3390/foods10081901
6. Mridula D, Saha D, Gupta R, Bhadwal S, Arora S, Kumar P, et al. Oil expelling from whole and dehulled sunflower seeds: Optimization of screw pressing parameters and physico-chemical quality. International Journal of Chemical Studies. 2020;8(4):4002-9. https://doi.org/10.22271/chemi.2020.v8.i4ay.10274
7. Gudzenko M, Vasyliv V, Mushtruk M, Zheplinska M, Palamarchuk I, Burova Z. Influence of geometric parameters of screw nozzles of twin-screw extruder-press on oil yield. Animal Science and Food Technology. 2021;12(3):5-17. https://doi.org/10.31548/animal2021.03.001
8. Gudzenko M, Vasyliv V, Mushtruk M, Zheplinska M, Burova Z. Research on the effectiveness of means for intensifying oil compression in twin-screw extrusion presses. Animal Science and Food Technology. 2022;13(4). https://doi.org/10.31548/animal.13(4).2022.7-18
9. Alabi K, Busari R, Joel O. Development and Performance Evaluation of a Variable-Pitch Tapered-Shaft Screw Press for Palm Oil Extraction. Gazi University Journal of Science Part A: Engineering and Innovation. 2022;9(2):49-61. https://doi.org/10.54287/gujsa.1069996
10. Mursalykova M, Kakimov M, Kassenov A, Iskakov B, Sergibayeva Z, Kaspakov E. Mathematical modeling of screw press configuration for processing Safflower Oil. Applied Sciences. 2023;13(5):3057. https://doi.org/10.3390/app13053057
11. Iskakov B, Kakimov M, Kudelski R, Mursalykova M, Kassenov A, Satayeva Z, et al. Improving the Technology of Primary Purification of the Safflower Oil Using Secondary Products of Processing on a Biological Basis. Foods. 2023;12(17). https://doi.org/10.3390/foods12173275
12. Zikri A, Aswan A, Erlinawati E, Fatria F, Pratama Y, Anggraini T. Uji Kinerja Screw Oil Press Machine Ditinjau dari Rendemen dan Kualitas Minyak Kelapa yang Dihasilkan. FLUIDA. 2020;13(2):46-53. https://doi.org/10.35313/fluida.v13i2.2305
13. Muhammad Afriza Zaini T, Ali S, Saputra M, Jamaluddin. Pressure Analysis of Oil Mill Screw Press Machine in PT. Ujong Neubok Dalam. Jurnal Inotera. 2022;7(2):83-87. https://doi.org/10.31572/inotera.vol7.iss2.2022.id176
14. Mansor MN, Salleh SM, Fauzi MR, Yahya MN, Juahir A, Hassan H, et al. Total Lifespan Analysis of Screw Press Using Static and Dynamic Simulation. In: AIP Conference Proceedings. 2023. https://doi.org/10.1063/5.0121098
15. Charan G, Krishna AR, Swarup KT, Ali SkS, Mohiddin Sk. Design and fabrication of a high-yield edible oil expeller screw shaft. Interantional journal of scientific research in engineering and management. 2023;07(03). https://doi.org/10.55041/ijsrem18000
16. Sarbeni S, Saputra A. Identification of Screw Press Machine Damage Using Failure Mode And Effect Analysis Method in PT. Socfinfo Seunagan. Jurnal Inotera. 2023;8(1):123-127. https://doi.org/10.31572/inotera.vol8.iss1.2023.id225
17. Sakdasri W, Silangam P, Chummengyen S, Sukruay A, Ngamprasertsith S, Supang W, et al. Optimization of yield and thymoquinone content of screw press-extracted black cumin seed oil using response surface methodology. Ind Crops Prod. 2023;191. https://doi.org/10.1016/j.indcrop.2022.115901
18. Bako T, Obetta SE, Umogbai VI. Mathematical modeling of mechanical horizontal screw oil extractor. Agricultural Engineering International: CIGR Journal [Internet]. 2020; 22(2):244-254. Available from: https://cigrjournal.org/index.php/Ejounral/article/view/5521
19. Wang S, Wang J, Dong G, Chen X, Feng L, Su X, et al. Effect of Different Extraction Methods on Quality Characteristics of Rapeseed and Flaxseed Oils. Journal of Food Quality. 2022. https://doi.org/10.1155/2022/8296212
20. Bogaert L, Mathieu H, Mhemdi H, Vorobiev E. Characterization of oilseeds mechanical expression in an instrumented pilot screw press. Industrial Crops and Products. 2018 ;121:106-113. https://doi.org/10.1016/j.indcrop.2018.04.039
21. Kabutey A, Herák D, Mizera Č. Assessment of Quality and Efficiency of Cold-Pressed Oil from Selected Oilseeds. Foods. 2023;12(19):3636. https://doi.org/10.3390/foods12193636
22. Kabutey A, Herák D, Mizera Č. Determination of Maximum Oil Yield, Quality Indicators and Absorbance Spectra of Hulled Sunflower Seeds Oil Extraction under Axial Loading. 2022;11(18):2866. https://doi.org/10.3390/foods11182866
23. Kachur O, Korendiy V, Havran V. Designing and simulation of an enhanced screw-type press for vegetable oil production. Computer Design Systems. Theory and Practice. 2023;5(1):128-136. https://doi.org/10.23939/cds2023.01.128
24. Badigannavar R, Kavadamatti A, Kulkarni G. Temperature Based Fan Speed Controller Using Arduino. Interantional journal of scientific research in engineering and management. 2022;06(10). https://doi.org/10.55041/ijsrem16609
25. Li Y, Jin Z, Li Q, He L, Zhang Y, Song S. The Design of an Intelligent Screw Extruder Control System Based on Fuzzy Control. Lecture notes in electrical engineering. 2019;259-267. https://doi.org/10.1007/978-981-32-9698-5_30
26. Muliak N, Zdobytskyi A, Lobur M, Kaczynski R, Optimization of Electromechanical Systems by Intelligent Design Methods. 2022 IEEE XVIII International Conference on the Perspective Technologies and Methods in MEMS Design (MEMSTECH). Polyana (Zakarpattya). Ukraine. 2022; 65-69. https://doi.org/10.1109/MEMSTECH55132.2022.10002914
27. Household All Stainless Steel Oil Press Ltp200 Electric Small Household Commercial Cold And Hot Pressing Fully Automatic - Specialty Tools - AliExpress [Internet]. aliexpress.us. [cited 2024 Jan 2]. https://www.aliexpress.com/item/1005004330106945.html#navspecification

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