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REZUMAT TEZĂ DE DOCTORAT

Summary of PhD Thesis

CERCETĂRI PRIVIND CREŞTEREA PERFORMANŢELOR UNUI ECHIPAMENT DESTINAT OBŢINERII ULEIULUI DIN SEMINŢE DE STRUGURI

RESEARCH ON INCREASING THE PERFORMANCE OF AN EQUIPMENT TO OBTAIN OIL FROM GRAPE SEEDS

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CONTENT

FOREWORD

The doctoral thesis "Research on increasing the performance of an equipment intended to obtain oil from grape seeds" is structured on 7 chapters, developed on a number of 203 pages, which include 160 figures and graphs, 32 tables, 168 mathematical relationships and a bibliographic list formed from 154 references. Also, the present paper includes a list of notations and symbols, and at the end, a series of appendices presenting materials and informative data related to the studies and researches presented in the present paper are presented.

This doctoral thesis presents a synthesis of theoretical and experimental research regarding the process of obtaining oil from grape seeds using a continuous mechanical screw press. The main objective of the research carried out in the thesis is to study the possibilities of increasing the performances of a continuous mechanical screw press by highlighting and intervening on the main influencing factors.

In the first chapter of this thesis, a brief presentation of the importance of reusing vegetable waste from the wine industry in order to obtain oil from grape seeds, as well as the objectives pursued in the elaboration of the thesis, is made.

In chapter 2, entitled "The current state of research and achievements in the field of technologies and equipment used to obtain grape seed oil", the methods of obtaining grape seed oil and a critical analysis of the extraction methods are presented first. of grape seed oil. Another important point of this chapter is the constructive and functional analysis of the presses for the extraction of oil from grape seeds. At the end of this chapter, conclusions are presented regarding the importance of choosing the method of extracting oil from grape seeds according to the desired quantity and quality of the oil.

Chapter 3, called "Physico-chemical properties of grape seeds", presents, first of all, the morphological and microscopic structure of grape seeds as well as their chemical composition, determined by researchers in the field. Also, in this chapter, the physical-mechanical properties are presented which include the physical indicators, mechanical properties and quality indicators of the grape seeds.

Chapter 4, entitled "Contributions to the mathematical modeling of the pressing process a grape seeds", presents the influence of physical characteristics, as well as the influence of functional and technological parameters on the process of extracting oil from grape seeds. Also, theoretical research is carried out regarding the work process and dimensional calculation elements for the construction of screw presses. In addition, mathematical models regarding the process of seed pressing with the help of screw presses are highlighted for calculating the working capacity of screw presses and the power required to actuate screw presses (by estimating it based on its components or based on the drive model of helical conveyors), as well as some mathematical models for predicting the flow of extracted oil, both in screw presses, models obtained by applying the theory of dimensional analysis. Also, the characteristic parameters aimed at increasing the performances of a screw press for obtaining oil from grape seeds and mathematical models were proposed for describing the influence of the diameter of the pomace discharge nozzles on the degree of oil extraction, the description of the influence of the feed rate on the degree of oil extraction, description of the power required to drive the press depending on the pressing time (for screw presses).

In chapter 5, named "MEF analysis of the screw of the NF80 mechanical press and the behavior of the grape seeds in the pressing process", the 3D model of the screw press was created in the first phase, after which a 3D numerical simulation study with finite elements for simulating the behavior of the structure of two screws with a different distance between turns (one with a distance between turns of 16 mm, and the second of 22 mm), subjected to the stresses that arise in the pressing chamber. Later, a study was carried out with the aim of simulating the behavior of a grape seed placed in a vertical and horizontal position and subjected to a force.

Chapter 6, entitled "Experimental research on increasing the performance of a mechanical press intended to obtain oil from grape seeds", includes in the first part the obtaining and conditioning of grape seeds in which the methodology of conditioning grape seeds in order to obtain oil from grape seeds is presented. After that, a series of preliminary experimental determinations were carried out, namely the study of the physical and mechanical properties of grape seeds. After these determinations, experimental tests of a continuous mechanical screw press were made in order to increase the performances in obtaining oil from grape seeds.

Chapter 7, titled "General conclusions. Contributions. Perspectives", presents the general conclusions derived from the theoretical and experimental research addressed in the thesis, as well as a series of personal contributions to the completion of the doctoral thesis. Also, some future directions of research on this topic are highlighted, which can be further addressed by other researchers.

In accordance with the above, the theme of the doctoral thesis addresses a relevant field nowadays and makes a technical-scientific contribution to the field.

THANKS

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LIST OF NOTATIONS

ϕ	sphericity
ρ	seed density [g/cm^3]
μ	relative compression of the particle, [N/mm]
φ	inclination [degrees]
φ_n	helix inclination [degrees]
ρ_v	bulk density of transported seeds
v_{ev}	velocity of the material through the outlet end of the pressing chamber, [m/s]
v_x	material velocity component along the x-axis [m/s]
v_z	material velocity component along the z axis [m/s]
τ	the unit shear stress
ξ	dimensionless variable having the meaning of the relative height of the considered point, related to the bottom of the channel
δ	the radial clearance of the screw in the press chamber
δ_a	allowed voltage
δ_o	yield strength of mild steel, [N/mm2]
σ_{max}	maximum unit effort
σ_e	equivalent effort
τ_{max}	maximum twisting unit effort
η	efficiency of grape seed oil extraction [%]
η_a	apparent viscosity [Pa·s]
η_m	mechanical efficiency
η_t	transmission efficiency
α	wrap angle [degrees]
ε	compression ratio of the material in the press chamber; n- screw speed, [rpm]
β	the coefficient of lateral expansion, in the x direction, of the seeds in the feeding area
Δp	pressure at the end of the screw [Pa]
Δt	rotation period, [s];

Ac	cross-sectional area of the sawdust outlet, [m^2]
A_m	area of the section occupied by seeds [mm^2]
A_p	pressing area of the screw turns, [mm^2]
C	constant of integration
d	diameter of the sawdust outlet, [m]
d_d	the depth of the spiral of the screw in the area of discharge of scrap [mm]
d_f	depth of the auger in the seed feeding area [mm]
D	effect of exhaust nozzle diameter [mm]
D_a	arithmetic mean diameter [mm]
D_c	cylinder diameter [mm]
D_e	outer diameter of the screw, [m]
D_g	geometric mean diameter [mm]
D_r	strain at breaking point of seeds [mm]
D_{sh}	diameter of the core (shaft) of the auger, [mm]
E	the modulus of elasticity of the material
F	axial force required to extract the oil, [N]
f_c	collar friction force, [N]
Fc	the resistance force of the material pushed through the outlet at the end of the press chamber, [N]
F_r	force required to break the seeds [N]
F_S	the force used to crush particles pressed on one mm2 of surface area occupied by the particle [N]
Ft	the force transmitted along the length of the shaft, [N/mm]
g_O	weight of oil extracted by pressing [g]
g_s	weight of the batch of grape seeds from which the oil was extracted [g]
G	Thickness [mm]
G_m	The mass flow rate of the auger
H	seed hardness [N/mm]
h	the maximum depth of the spirals of the auger in the discharge zone, [mm]
K	force constant
k_w	speed coefficient

k_{w1}	Slip coefficient
k_{w2}	the speed averaging coefficient
L	length [mm]
lc	exhaust hole length, [m]
L_c	the mechanical work required to push the sawdust through the outlet, [J].
L_S	screw length, [mm]
L_{pr}	the mechanical work done to press the grape seeds, [J]
l	width [mm]
M	mass of seed sample before drying [g]
M_a	absolute mass [g]
Mo	mass of seed sample after drying [g]
M_f	friction moment [Nm]
$M_{inc.max}$	maximum bending moment
n	screw speed [rpm]
N_1	engine speed, [rpm]
N_2	screw shaft speed [rpm]
O_T	total oil content of grape seeds (determined by solvent extraction) [%]
O_Y	oil yield (calculated) [%]
p	pressure [Pa]
p_m	screw pitch, [mm]
P	seed transport power from the feeding area to the discharge area, [kW]
P_a	axial load
P_{cr}	critical load
P_e	power absorbed by the screw press [kW]
P_{ev}	the power required to evacuate the scrap, [kW]
P_{fr}	the overcoming power of the friction between the auger and the seeds, [kW]
P_m	electric motor power, [kW]
P_r	the pressure produced by the turns of the screw, [MPa]
P_S	power required to drive the screw press, [kW]
P_{pr}	grape seed pressing power, [kW]
P_V	the pressure that the pressing chamber must withstand, [MPa]

Q	theoretical capacity of the screw press, [kg/h]
Q_V	volumetric capacity of the auger, [m3/h]
r_c	collar radius, [mm]
r_m	auger core radius, [mm]
R_{Ubrut}	crude oil yield [%]
$R_{Ufiltrat}$	filtered oil yield [%]
R_x	the rebound of the v_x component
R_z	the slope of the v_z component
R_1	small wheel radius, [mm]
R_2	larger wheel radius, [mm]
s	screw pitch [m]
S	cross-sectional area of the pressing chamber, [m2]
S'_{i0}	axial displacement on the average speed circumference
T	screw torque, [Nm]
U	humidity [%]
v	average seed movement speed along the auger, [m/s]
V_{per}	Peripheral velocity in the wall area of the pressing chamber
V_u	Unit volume [mm3]
V_{te}	theoretical volume of material displaced by the screw turn during one complete rotation towards the discharge area [m3]
V_x	Peripheral velocity along the x-axis direction
V_z	Peripheral velocity along the z-axis direction
W	maximum seed compression force, [N]
w_e	angular velocity [rad/s]
W_{1000}	mass of 1000 grape seeds [g]
w_{med}	the mean velocity vector of the transported seeds
Wm	the equatorial modulus of elasticity
Wpm	the polar resistance module
Y	oil yield [%]

CHAPTER 1
INTRODUCTION

1.1 General aspects

Grape seeds are the main by-products of grape processing industries such as the grape juice and wine industries. A grape berry contains about two seeds that constitute about 5% of the weight of the grape [Choi and Lee, 2009]. However, the number and weight of the seeds varies depending on the average size of the berry and the grape variety. Worldwide, more than 3 Mtons of grape seeds were thrown away annually. More than 20% by weight of grape production usually becomes waste during winemaking. Grape seeds contain fiber, protein, lipids (fat and oil), carbohydrates, minerals and between 5% and 8% polyphenolic compounds (such as tannins), depending on the variety and other factors such as climate, soil and degree of baking [Bordiga, 2015].

Most often, grape seeds are used for oil extraction, due to the rich composition of bioactive substances needed in industries such as food, pharmaceutical and cosmetics. The oil content of grape seeds ranges from 10% to 20% and has a high content of vitamin E, which depends on the grape variety, origin and environmental growing conditions [Choi and Lee, 2009]. Grape seed oil contains approximately 90% mono- and poly-unsaturated fatty acids, where linoleic acid (an essential fatty acid for human metabolism) is the most abundant [Duba and Fiori, 2016]. In general, oleic, stearic and palmitic acids are in minor amounts. The high content of unsaturated fatty acids makes grape seed oil a nutritious, high-quality oil important for human health and of high commercial value.

1.2 The importance of using vegetable waste from the wine industry to obtain grape seed oil

The processes in the wine production industry are accompanied by the generation of a large flow of waste, namely organic waste (peels, seeds, tails, wood solids, etc.), waste water, greenhouse gas emissions (CO_2, organic compounds volatiles, etc.) and inorganic waste, [Kwatra, 2020].

At the global level, especially in the last 10 years, a rapid increase in the performance of the production process is required by generating a minimal or non-existent footprint on the environment, and the wine industry is also subject to legislative pressures for production efficiency, [Kwatra, 2020].

The pomace comes out of the production flow at the end of the grape pressing process and contains mainly the skins in which the grapes, pulp and seeds are wrapped, but it can also contain bunches if the destemming step is omitted (fig. 1.6). Therefore, pomace is the main residue resulting from the processing of grapes to obtain juice and wine, constituting 20–25% of the weight of grapes, [Dávila et al. 2017; Beres et al. 2017].

As I mentioned above, the marc is mainly composed of skins, grape seeds and, if applicable, bunches, fig. 1.7. Taken individually, each of these materials have in their structure compounds that can be extracted by various technological methods and that are used in other production processes, such as the food, agricultural, pharmaceutical, etc.

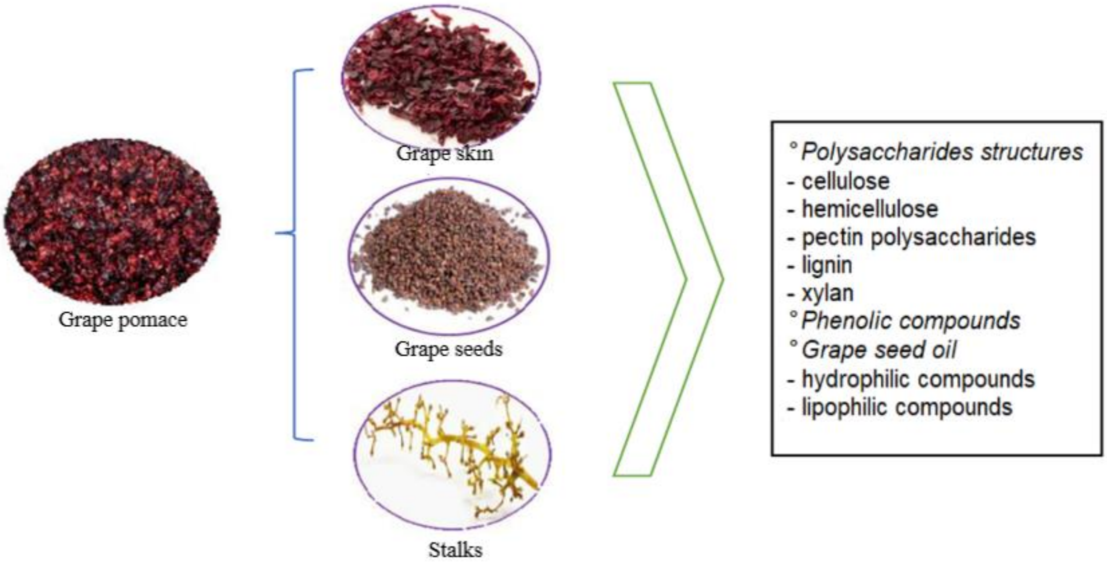


Fig.1. 7 The composition of the marc

[Spinei M., et. al., 2021]

Grape seeds represent the main waste product from the pomace resulting from industries processing grapes, namely the grape juice and wine industries. A grape berry contains approximately two seeds, constituting approximately 5% of the weight of the grapes [Choi and Lee, 2009]. However, the number and weight of the seeds vary depending on the average size of the berries.

The extraction of oil remains the most important method for utilizing grape seeds due to its numerous applications and benefits in various industries. Grape seed oil is both a cost-effective resource and a solution to the waste problem in winemaking, making it profitable. However, in contemporary times, considering technological advancements, various chemical methods have been attempted to extract as many elements as possible from these seeds.

Grape seed oil appears to be a promising competitor to fossil fuel sources due to the presence of unsaturated fatty acids in its constituents. Biodiesel production, including refining after extraction, is an economical and environmentally friendly alternative in regions with high wine production volumes [Fernández et al., 2010; Gorna's et al., 2016; Hariram et al., 2019].

In conclusion, regarding grape seed oil, some constituents exhibit remarkable antioxidant and anti-inflammatory activities. Essential fatty acids such as linoleic acid, vitamin E, and phytosterols, as well as hydrophilic phenols, seem promising not only as nutritional compounds but also as therapeutic agents. Many of them are also in experimental studies to explore their anticancer properties. Non-food industries, including pharmaceuticals and cosmetics, can also benefit from grape seed oil. Given the vast expansion of grape cultivation, the use of compounds related to winemaking has also become a subject of environmental impact, added to the global economic market.

1.3 The objectives of the doctoral thesis

By carrying out theoretical and experimental research regarding the process of obtaining oil from grape seeds, carried out within this thesis, it was aimed to study the possibilities of increasing the performance of a continuous mechanical screw press by highlighting and intervening on the main influencing factors, representing the general objective of the thesis.

In order to fulfill the general objective of the work, it was necessary to achieve the following specific objectives:

- Analysis of the current state of methods, technologies and equipment used to obtain vegetable oils;
- Documentary study on the factors that influence the pressing process of oleaginous materials;
- Mathematical modeling of the oil pressing and extraction process using screw presses;
- Carrying out theoretical and experimental research on the physical-mechanical properties of several types of grape seeds;
- Development of finite element analysis models of the interaction between the oleaginous material and the working organs of continuous mechanical screw presses;
- Carrying out experimental research on the methodology of separating grape seeds from pomace;
- Carrying out experimental research on the grape seed pressing process;
- Carrying out experimental research on the influence of some parameters on the pressing process at screw presses;
- Carrying out experimental research on energy consumption when pressing grape seeds.

CHAPTER 2
THE CURRENT STAGE OF RESEARCH AND ACHIEVEMENTS IN THE FIELD OF TECHNOLOGIES AND EQUIPMENT USED TO OBTAIN GRAPE SEED OIL

2.1 Methods of obtaining oil from grape seeds

In general, oilseed oils can be extracted by several methods depending on the resources and needs of the producer, but more importantly depending on the nature and oil content of the raw material and the quality of the oil obtained. The methods of obtaining oil from grape seeds can be: chemical extraction, extraction with supercritical fluids, extraction by distillation and mechanical extraction.

2.2 Critical review of grape seed oil extraction methods

Each method of oil extraction has its own advantages and disadvantages in terms of economic, practical and environmental aspects. Therefore, the best method depends on the specific results desired

Tabel 2. 1 Advantages and disadvantages of mechanical and chemical methods of oil extraction from seeds,

[Bhuiya et al., 2016; Keneni et al., 2017]

Mechanical Extraction		**Chemical Extraction**	
Advantages	*Disadvantages*	*Advantages*	*Disadvantages*
Virgin oil is more sought after	They may be ineffective in processing some seeds	Higher yields in oil extraction	A virgin oil cannot be obtained
There is no potential for solvent contamination	Relatively lower oil yields compared to other methods	Hexane can be recovered and reused, reducing costs	Potential for solvent contamination of oil
Relatively cheap after initial capital costs	Operators need experience to get the best results	Technology in full development	Safety issues and environmental concerns regarding the use of hexane
The cost of consumables are low	High dependence on seed moisture content	It can be an ecological method if related processes are used (supercritical fluid)	Very expensive if the hexane cannot be recovered
Whole seeds can be processed	A process of filtering or refining the oil is required	The most used method at the industrial level	Batch processing
Reduced environmental problems	Press blockages may occur if the parameters are not set correctly		It requires grinding the seeds
Continuous processing	-	-	High initial investment
Unskilled labor	-	-	It requires skilled labor
The resulting meal can be used in animal feed, flour or natural fertilizer	-	-	-
The obtained oil contains a higher nutritional value	-	-	-

Mechanical seed pressing continues to be the best technology among physical vegetable oil extraction processes, meeting the needs of both small farmers and large-scale processors. This type of equipment combines small-scale efficiency with low costs compared to the other methods mentioned. Another significant advantage is that the residues resulting from pressing, such as cake or sawdust, can be used as fertilizer or animal feed, without containing toxic solvents.

2.4 Constructive and functional analysis of grape seed oil extraction presses

Screw presses consist of a screw rotating in a press chamber which may be a perforated horizontal cylinder or may consist of regularly spaced metal bars (this spacing may vary from 0.5 to 0.1 mm); the oil flows along this cylinder. At the head of the screw, a cone is formed that partially obstructs the discharge area of the sawdust, causing the pressure required to extract the oil to increase. In fig. 2.9 shows the sectional view of the mechanical screw press, being the simplest and most used model, on a small and medium scale.

The performance of the screw press mainly depends on the pressure application/development. Unlike a hydraulic press where the applied pressure can be set to the desired level, the pressure developed in a screw press is quite difficult to control and measure. The pressure measured on some equipment was up to 196 MPa, [François 1974].

From the entry of the seeds into the screw press, until the discharge in the form of sawdust, which represents a continuous process, the material passes through several areas where their volume is reduced, as in fig. 2.10.

The compression necessary to extract the oil and the maximum compaction of the material is achieved by gradually reducing the available volume along the press.

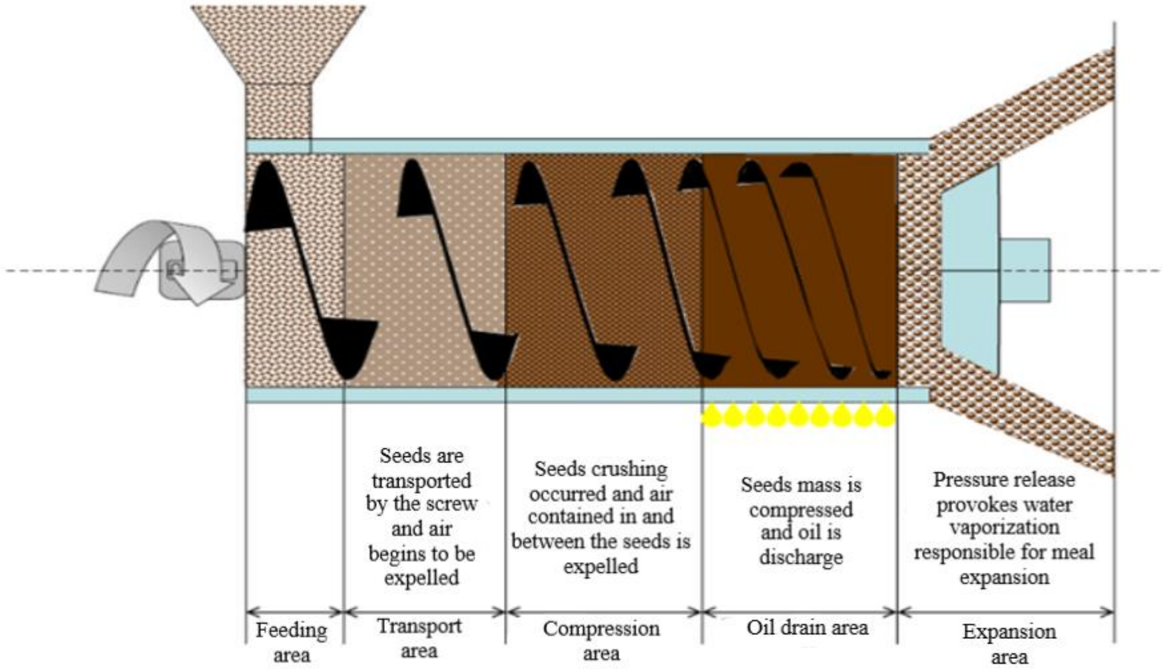


Fig.2. 10 The stages of pressing the oleaginous material

[Savoire et al., 2013]

The main component parts of an auger press are: transmission, press bearings, feed area, press chamber, auger and chip outlet.

The press consists of:

- The feeding area that includes a hopper, a helical conveyor and a scraper that together prevent the blocking of the oily material;

- The screw of the press which consists of several irregular segments to create a higher pressure, a better crushing of the seeds and which prevents the blocking of the material in the press chamber. All the components that make up the auger are supported on a splined shaft.

- The pressing chamber consists mainly of rings that have different thicknesses depending on the stage at which the seeds are in the oil extraction process. In the area of feeding and advancing the material, the rings are more frequent and of medium thickness to prevent loss of material and clogging of the slots, since in this area crushing of the material begins and the release of oil is minimal. In the area of crushing and compaction of the seeds, the rings are fewer in number with a smaller thickness, this is where most of the oil is released. In the area of the discharge of the scrap, the fewest rings with the greatest thickness are found.

- The meal discharge slot consists of a metal cone, which, depending on the manual adjustment made with the help of a spring and a nut, can completely close the pressing chamber or, depending on the type of pressed seeds, a certain distance is established where the solid mass of the material will be discharged. Through this system, solid mass comes out in the form of very thin flakes.

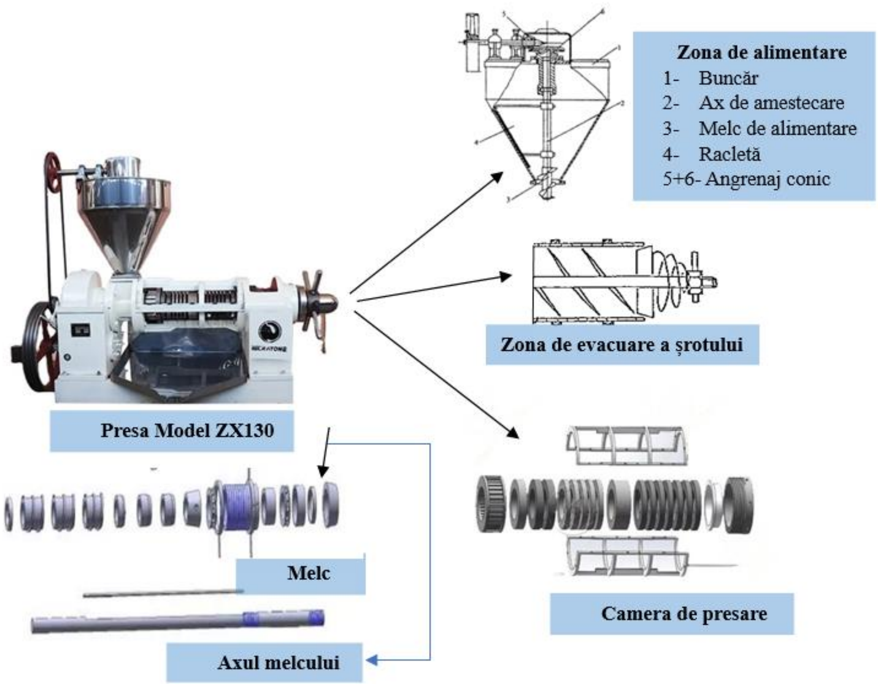


Fig.2. 12The components of the MCRAYONE screw press model ZX130

[https://www.alibaba.com]

CHAPTER 3
PHYSICO-CHEMICAL PROPERTIES OF GRAPE SEEDS

3.1 Morphological and microscopic structure of grape seeds

Grape seeds have a bipartite protective coat that joins in the middle of the seed to form a ridge on the ventral side of the seed. The outer seed coat consists of several thin layers that protect the embryo against adverse environmental conditions. The surface of the outer tissue varies from smooth to rough. The endosperm and tissue that surrounds and nourishes the seed embryo is covered on the ventral side of the seed due to the two main longitudinal folds. On the side where the chalaza is evident, there is a vascularized surface that extends to the apical groove, passing medially along the ventral side and over the apex, ending on the dorsal side of the seed as an enlarged lignified chalaza. Although the outer coats of grape seeds are not usually preserved in grape seeds, the external morphology of the seeds is mirrored in the lignified part that lies below the seed coat, which is also often preserved in fossils. The combination of paired ventral folds and dorsal chalaza is unique to Vitaceae, [Chen et al., 2007].

3.2 Chemical composition of grape seeds

The transverse section from the mid-zone of the seed served to distinguish five zones: cuticle (Cu) and epidermis (Ep), outer integument (OI) composed of large parenchymal cells; median integument (MI) composed of two layers of cells; inner integument (II) with three layers of cells; endosperm and embryo. In this section of fig. 3.9, the endosperm has been replaced by an empty space (Em). The thickness of the cell layers of the OI was greater in the ventral face (VF) than in the dorsal face (DF). The cells of the outer tissue of the OI became deformed and plasmolyzed (Pl-Pa); the cells of the inner cellular tissue were still turgid, and the vacuoles of these cells were completely and intensely stained (Ta-Pa); Fo = a small depression; R = a groove, ridge or seam in the tissue, marking the line between two halves that have fused in the embryo, [Spinei et al., 2021].

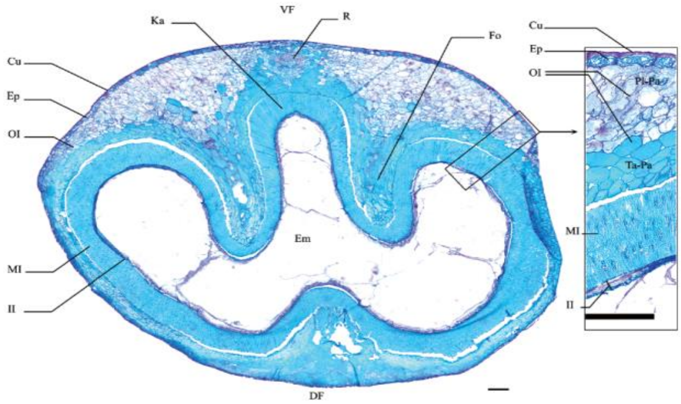


Fig. 3. 9 Structure of grape seed, transverse section and stained with toluidine blue
[Spinei et al., 2021]

3.3 Physical indicators of grape seeds

The physical indicators of the seeds have influence or direct connection with the processing processes, with the extraction of the final products, the quality of these products and the energy consumption. In general, the physical indicators are: color, size and shape of seeds, geometric and arithmetic diameter, sphericity, unit volume, hectoliter mass, relative mass of 1000 seeds, absolute mass, specific mass, flow capacity, density, inter-granular space or the porosity and hygroscopicity of the seed mass.

3.4 Mechanical properties of grape seeds

The mechanical properties of oilseeds are highlighted by subjecting them to different stresses (compression, shear). During these stresses, the variations in the size of the seeds (the deformations) and the forces necessary to produce these deformations are followed, thus different characteristic curves are drawn. Taking into account the efforts to which the seeds are subjected during processing, the following characteristics are highlighted: resistance to compression, resistance to shear, modulus of elasticity and rigidity of the shells, degree of adhesion of the shells to the endosperm, resistance to crushing.

The moisture content, the tissue structure of the layers and the working section are parameters that influence the shear strength, while the compressive strength is dependent on the moisture content and the thickness of the coating, [Danciu, 1997].

CHAPTER 4
CONTRIBUTIONS TO THE MATHEMATICAL MODELING OF THE GRAPE SEED PRESSING PROCESS

4.1 The influence of the physical characteristics of grape seeds in the oil extraction process

Generally speaking, about oilseeds, studies have been carried out to identify how certain parameters can influence the yield of extracted oil. In the last decade, in the research carried out with the aim of improving the oil extraction performance, the physical characteristics of the material subjected to pressing, such as the variation of moisture content, physical and thermal pre-treatments, even the type of seeds, were taken into account.

4.2 The influence of functional and technological parameters on the process of grape seed oil extraction

Pressing the oleaginous material has the advantage of obtaining a qualitative oil, in which most of the nutrients specific to the seed type are maintained, but the major disadvantage is the lower yield which can vary between 90-98%. From the perspective of this disadvantage, many researches have considered the improvement of this method by increasing the performances, correlating process variables such as pressure, temperature, screw speed and pressing time.

4.3 Theoretical research on the working process of mechanical screw presses

The operation of the screw press is simple, but complicated from the point of view of modeling the mechanical process. The oilseeds are loaded into the feed area of the press, after which they are transported to the compression area. During the period in which the seeds are moved, the air in the voids of the material is removed, the seeds rotate inside the pressing chamber with the rotation of the screw and in the last phase the seeds are cracked and begin to lose their original shape. The uninterrupted feeding and transport of the seeds causes pressure to increase in the discharge head of the press, which helps to compact the seeds and release the oil. When the maximum value of the pressure imposed by the pressing head has been exceeded, the discharge of the scrap begins [Bako et al. 2020].

Following the transport of the seeds from the feeding area to the discharge head, frictional forces appear between the material-screw-the inner walls of the pressing chamber. For a proper transport of the seeds, the force induced by the auger together with the frictional force between the material and the pressing chamber must be greater than the sum of the frictional force between the material and the auger and the pressing forces of the seeds. If this is not respected and things are reversed, then the sliding phenomenon appears, and transport is reduced or even will not exist [Beerens, 2007].

Speaking further about the description of the trajectory that the material travels along the screw, in fig. 4.34 shows a helical spiral with a constant pitch in the radial direction, but it is characterized by different values of the inclination at the top of the spiral R and at the base of the spiral or the core of the Screw Rn, [Jinescu, 2007].

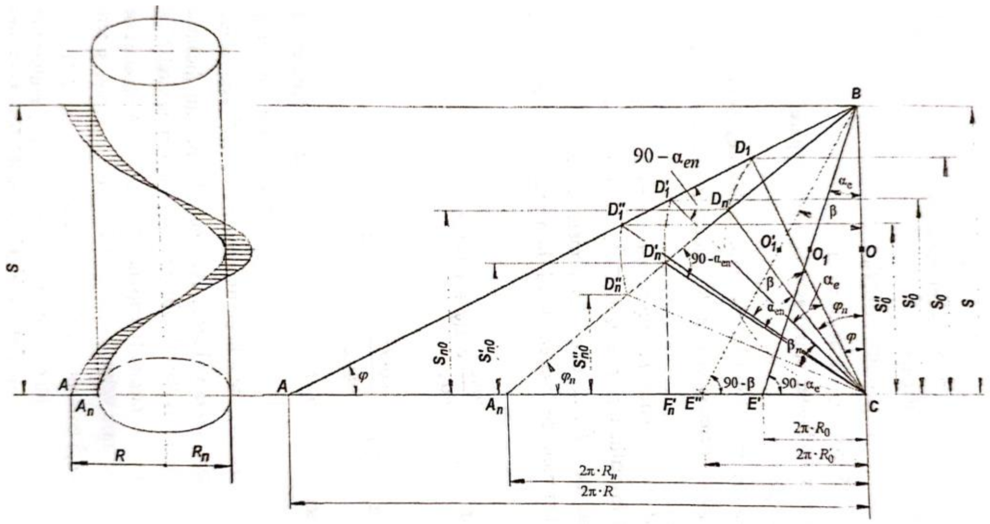


Fig.4. 34 Displacement of the material on the development of the spiral of the auger by the length of one step, at the top of the spiral (ABC) and at the base of the spiral (A_nBC)

[Jinescu, 2007]

The seed particles move along the axis of the screw on helical lines with inclinations varying from φ (helix tip) to (90°-α_e) at the point E' where $\overline{CE'}$ is located on the circumferential direction. Therefore, the movement in the direction of the axis of the screw is made between the values S_0' at the tip of the spiral of the screw and the inclination of the spiral (90°-α_e) corresponding to the hypotenuse $\overline{BE'}$, fig. 4.34.

In conclusion, the spiral of the Screw can be considered to be made up of many helical lines each with a different inclination. The lines that generate flow, incline φ (the tip of the spiral) to (90°-α_e), and the axial displacement determined by the spiral at inclinations φ_i is S_i'.

Taking into account, as in general, the flow of seeds through the helical channel behaves non-Newtonian, the equation of motion takes the following form [Renert, 1971]:

$$\eta_a \cdot \left(\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2}\right) + \frac{\partial v_z}{\partial x} \cdot \frac{\partial \eta_a}{\partial x} + \frac{\partial v_z}{\partial y} \cdot \frac{\partial \eta_a}{\partial y} = \frac{\partial p}{\partial z} \quad (4.30)$$

where: η_a- apparent viscosity, (Pa·s); v_z- material velocity component along the z axis, (m/s); p- pressure, (Pa).

The speed of oilseeds inside the press chamber, along the screw, is treated by Renert, 1971, first from the perspective of longitudinal flow, then from the perspective of transverse flow. Thus, the longitudinal flow of the material does not take into account the apparent viscosity η_a on the width of the auger channel, and the influence of the side walls of the channel is considered negligible, therefore from the relation (4.30) we obtain:

$$\eta_a \cdot \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial v_z}{\partial y} \cdot \frac{\partial \eta_a}{\partial y} = \frac{\partial p}{\partial z} \tag{4.31}$$

By integration we get:

$$v_z = \frac{1}{\varepsilon+1} \cdot \left(\frac{\bar{p}}{m}\right)^{\varepsilon} \cdot h^{\varepsilon+1} \cdot [(\xi - \xi_0)^{\varepsilon+1} + C] \tag{4.34}$$

where: $\varepsilon = 1/v$; $\xi = y/h$; ξ – dimensionless variable having the meaning of the relative height of the considered point, related to the bottom of the channel; C – integration constant.

The peripheral velocity along the z-axis can be determined with the relation:

$$V_z = \pi \cdot D_c \cdot n \cdot \cos\varphi \tag{4.36}$$

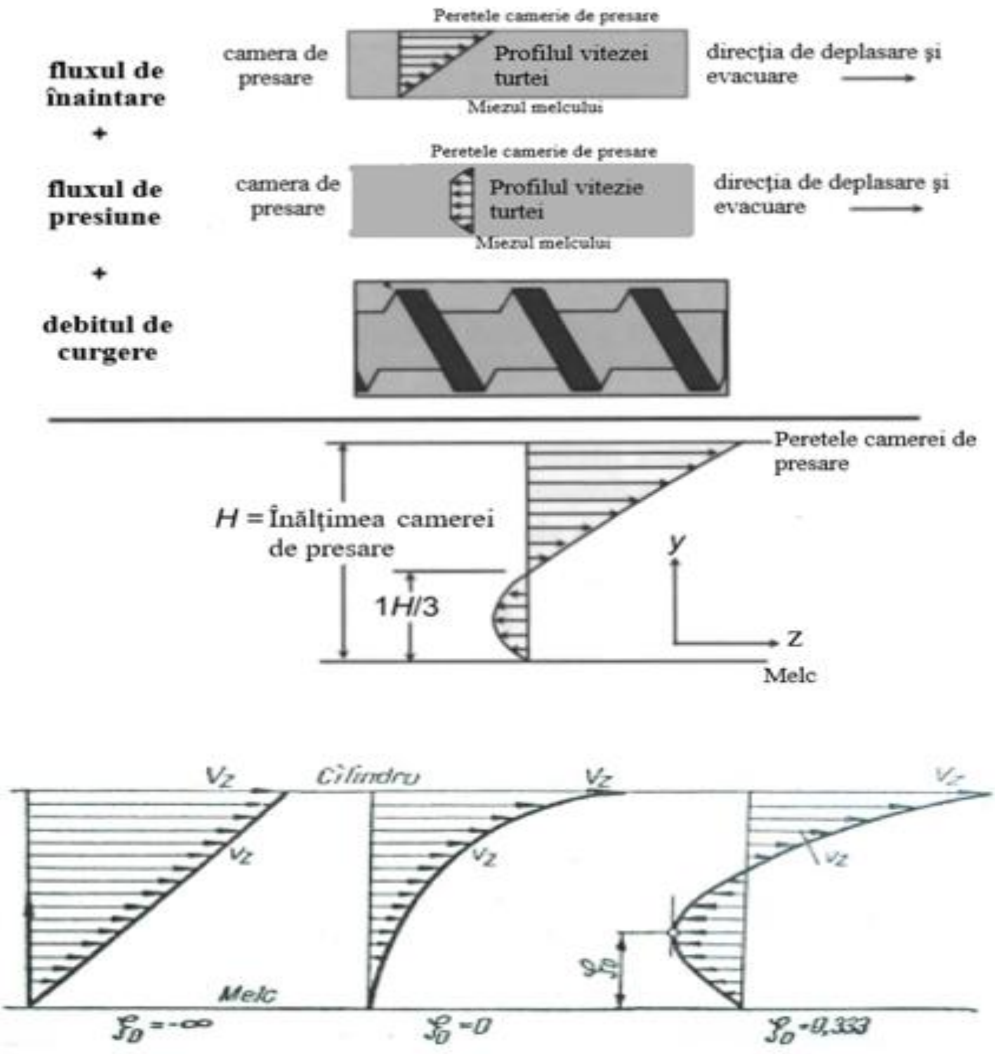


Fig.4. 37 Velocity profile of the cake through the press chamber section,
[Renert, 1971; Wagner et al. 2014]

In the case of transverse flow, along the x-axis direction, the velocity component V_x has the following form:

$$V_x = \pi \cdot D_c \cdot n \cdot \sin\varphi \tag{4.39}$$

They will be obtained by analogy with the relations of the longitudinal flow, the speed on the x axis and the slope:

$$v_x = \frac{(\xi - \xi_{0x})^{\varepsilon+1} - {\xi_{0x}}^{\varepsilon+1}}{(1 - {\xi_{0x}}^{\varepsilon+1}) - {\xi_{0x}}^{\varepsilon+1}} \cdot V_x \tag{4.40}$$

Fig. 4.37 shows the velocity gradients for these three flows and sums the resistance and pressure flow profiles to show a typical cake flow profile in the press chamber section. Pressure flow aids mixing as reverse flow increases the mixing action of the material in the press chamber. The material close to the cylinder wall moves with a high velocity in the transverse direction of the channel, while the material two-thirds of the pressure chamber height from the core of the screw has a zero velocity, [Wagner et al. 2014].

4.4 Elements of dimensional calculation for the construction of screw presses

In the following, calculation elements are presented for the execution of the design of some screw presses. The authors of the analyzed studies had slightly different perspectives by which they chose to approach the most important calculation elements for designed screw presses.

Habib et al., 2019, primarily dealt with the press auger, which has a slightly atypical shaft, in that it is extended and exits the press chamber in the direction of the scrap discharge, where it connects to the electric drive system.

The pressure that can also be supported by the press chamber was determined by the following formula:

$$P_V = \frac{2t\delta_a}{D_i} \tag{4.53}$$

where: P_V- the pressure that the pressing chamber must withstand, [MPa]; t și D_i- the thickness and internal diameter of the pressing chamber, (0,27 δo), [MPa]; δ_o- tensiunea admisă curgere a oțelului moale.

The power required by the electric motor to drive the screw press can be determined using the expression below as:

$$P_m = \frac{P_S}{\eta_m \cdot \eta_t} \tag{4.54}$$

where: P_m- electric motor power, [kW]; P_S- the power required to operate the screw press, [kW]; η_m- mechanical efficienc; η_t- transmission efficiency.

$$P_S = 4{,}5 \cdot Q_V \cdot L_S \cdot \rho \cdot g \tag{4.55}$$

where: Q_V- volumetric capacity of the auger, [m^3/h]; L_S- length of the screw, [mm].

The determination of the capacity of the press for oil extraction can be calculated with the following expression:

$$Q = \pi \cdot D \cdot N \cdot Hcos\alpha \cdot (\text{pm}cos\alpha - e) \quad (4.56)$$

where: Q - theoretical capacity of the screw press, [kg/h]; D- average diameter of the screw, [mm]; N- speed of rotation, [rpm]; H - depth of the screw, [mm]; p_m - screw pitch, [mm]; e- the thickness of the spiral of the screw, [mm]; α - the angle of the spiral of the screw..

The force required for the translation and compression of the seeds can be calculated:

$$W = K\, cos(\alpha + \phi) \quad (4.57)$$

where: W- maximum seed compression force, [N]; K- force constant, [mm]; ϕ – friction angle, $\phi = tan^{-1}\mu$; α - the angle of the spiral of the screw; μ- static coefficient of friction.

The frictional force results from the movement of the screw:

$$F = K\, sin(\alpha + \phi) \quad (4.58)$$

where: F- the axial force required to extract the oil, [N].

In general, as in the case of this press, the supply is made with an electric gear motor. The rotation speed N, of the auger, can be varied depending on the needs and the specifics of the seeds used. The angular velocity $w_e, [rad/s]$, can be calculated using the formula:

$$w_e = \frac{2\pi N}{60} \quad (4.62)$$

The power absorbed by the screw press is calculated:

$$P_e = T \cdot w_e \quad (4.63)$$

The power of the electric motor to drive the screw press, was presented by Onwualu et al. 2006, as follows:

$$P_m = \frac{P_e}{\eta} \quad (4.64)$$

where: P_m- electric motor power, [kW sau hp]; P_e- power required for oil extraction, [kW]; η- operating efficiency;

4.5 Mathematical models of the seed pressing process using screw presses

In order to develop a mathematical model that describes the process of pressing oilseeds, many studies in the field were based on multiple experiments in which the input parameters of the process were varied, and the results were analyzed statistically or by other methods, obtaining empirical models. These models have a specific character to the conditions proposed in the experiment, therefore if the input data are changed, the model is no longer revealed and must be modified for the new input data.

A model was developed by Fakayode et al., 2019, in which for the extraction of oil from moringa seeds using a screw press also designed by them, parameters such as: seed moisture, U_s [%], (were used three values respectively 9, 10 and 11% humidity); seed preheating temperature, $T_î$ [ºC], (50, 60, 70, 80 and 90 ºC) and seed preheating duration, $t_î$ [min], (15, 20, 25, 30 and 35 minutes); the applied pressure, P_a [MPa], (5, 10, 15, 20 and 25 MPa). After the experiments, the data were analyzed from a statistical point of view, and the model obtained for the extracted oil efficiency (EUE, %) has the following form:

$$EUE = -582{,}22 + 84{,}12U_s + 1{,}16T_î + 7{,}83t_î + 3{,}19P_a - 4{,}51U_s^2 - 0{,}02T_î^2 - 0{,}16t_î^2 - 0{,}12P_a^2 + 0{,}19U_sT_î - 0{,}11U_st_î + 0{,}22U_sP_a + 0{,}02T_ît_î - 0{,}02T_îP_a + 0{,}02t_îP_a$$

$$R^2 = 0{,}77 \quad (4.74)$$

The positive terms in the above equation mean the direct relationship between the variable parameters and their interactions with the extracted oil efficiency (EUE), while the negative terms mean an inverse relationship between them. All variable parameters were observed to have a direct relationship with EUE. This implies that EUE showed an increase with the increase of these parameters. Moisture content was found to be the most significant factor affecting EUE.

4.6 Contributions to the mathematical modeling of the pressing process using continuous mechanical screw presses

The following relationship can be used to determine the volumetric flow rate of the press:

$$Q_v = V_{te} \cdot (1 - \varepsilon) \cdot n \cdot k \cdot 60 \qquad [\mathrm{m^3/h}] \qquad (4.84)$$

where: V_{te}- the theoretical volume of the material displaced by the spiral of the screw during a complete rotation towards the evacuation area, [m^3]; ε- the compression ratio of the material in the pressing chamber; n- screw speed, [rpm]; k- coefficient that takes into account the reverse flow of the material at the ends of the coil and the incomplete filling with material, (k= 0.2-0.035).

The theoretical volume of material displaced by the spiral of the screw during one complete rotation towards the discharge area can be calculated as follows:

$$V_{te} = \frac{\pi}{4}\left(D_e{}^2 - d_i{}^2\right)(s - \delta) \qquad [\mathrm{m^3}] \qquad (4.85)$$

where: s- the pitch of the spiral of the screw, [m]; δ- thickness of the spiral, [m]; D_e, d_i – outer and inner diameter of the spiral of the screw, [m].

To calculate the power required to drive the auger press, all components are taken into account, from seed feeding to sawdust discharge, including resistance forces encountered by the auger and running with no load. Therefore, the power required to drive the screw press can be calculated with the expression below:

$$P = \frac{P_{tr}+P_{pr}+P_{fr}+P_{ev}}{\eta} \quad [kW] \qquad (4.87)$$

where: P_{tr}- seed transport power from the feeding area to the discharge area, [kW]; P_{pr}- pressing power of grape seeds, [kW]; P_{fr}- the overcoming power of the friction between the auger and the seeds, [kW]; P_{ev}- - the power required to evacuate the scrap, [kW] η- the efficiency of the mechanical transmission

4.6.3 The characteristic parameters followed to increase the performance of a screw press for obtaining oil from grape seeds

Based on several preliminary experiments, the range of values to which the above-mentioned parameters can be varied is chosen, which are detailed in chapter 6. In addition, after the experimental determinations, the following coefficients related to the efficiency of the process are calculated:

- Efficiency of grape seed oil extraction (η):

$$\eta = \frac{O_Y}{O_T} \times 100 \quad [\%] \qquad (4.108)$$

where: O_Y- oil yield (calculated) [%]; O_T- total oil content of grape seeds (determined by solvent extraction) [%].

$$O_Y = \frac{g_O}{g_s} \times 100 \quad [\%] \qquad (4.109)$$

where: g_O- weight of oil extracted by pressing [g]; g_s- the weight of the batch of grape seeds from which the oil was extracted [g].

- Material balance efficiency (φ):

$$\varphi = \frac{g_O+g_ș}{g_T} \times 100 \quad [\%] \qquad (4.110)$$

where: g_O weight of oil extracted by pressing [g]; $g_ș$- the weight of the meal [g]; g_T- the total weight of grape seeds used by pressing [g].

- The losses (PD) :

$$PD = 100 - \varphi \quad [\%] \qquad (4.111)$$

CHAPTER 5
MEF ANALYSIS OF THE NF80 MECHANICAL PRESS SCREW AND THE BEHAVIOR OF THE GRAPE SEEDS IN THE PRESSING PROCESS

5.1 3D modeling of the screw press model NF80

The screw press used for this work is a product manufactured in Turkey, model NF 80, which includes the following components: an electric motor of 0.70 kW; a reducer; feeding funnel; the pressing chamber consisting of several areas comprising assembled components: the seed transport area, the oil discharge area, the press head where the grit is discharged; nozzles of different sizes; the screw; control panel.

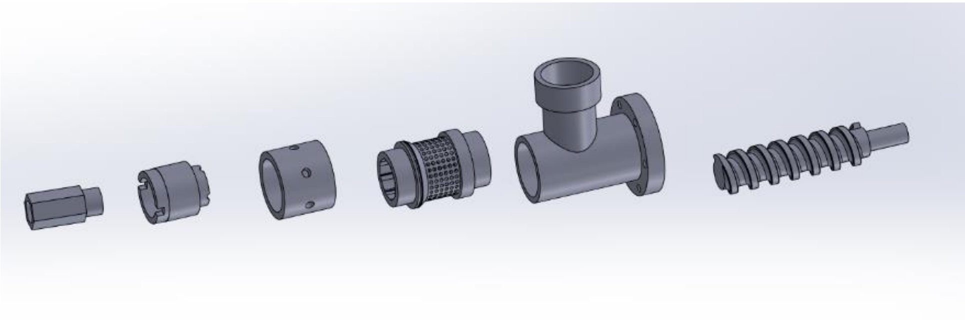


Fig.5. 2 The components of the NF 80 model press, modeled in 3D

The main focus of the three-dimensional modeling was on the most important components of the press such as: the screw, the component through which the press is fed, the pressing chamber, the pressing head and the discharge nozzle of the meal, fig.5.2.

For this work, I modeled in 3D two versions of snails that have different steps, to observe if there are differences in the flow of obtaining oil from grape seeds. One of the two screws has a pitch of 16 mm, fig. 5.4, and the second one has a pitch of 20 mm, fig. 5.5. This means that, in the case of the auger with the larger pitch, the spiral will be thinner and rarer.

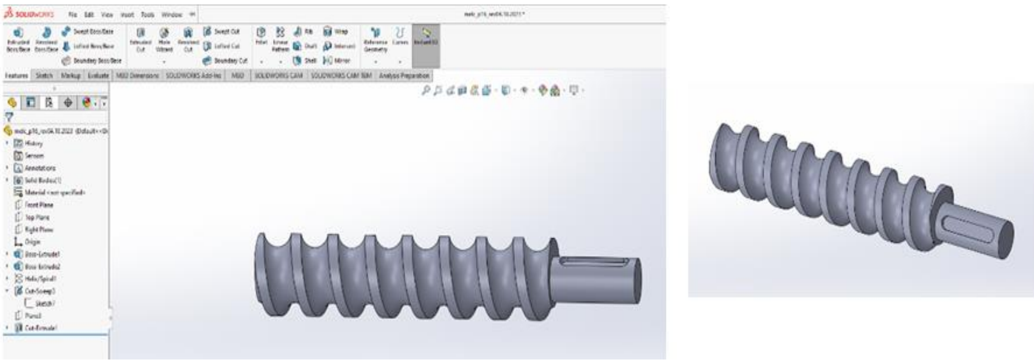


Fig.5. 4 NF 80 press screw with 16mm pitch

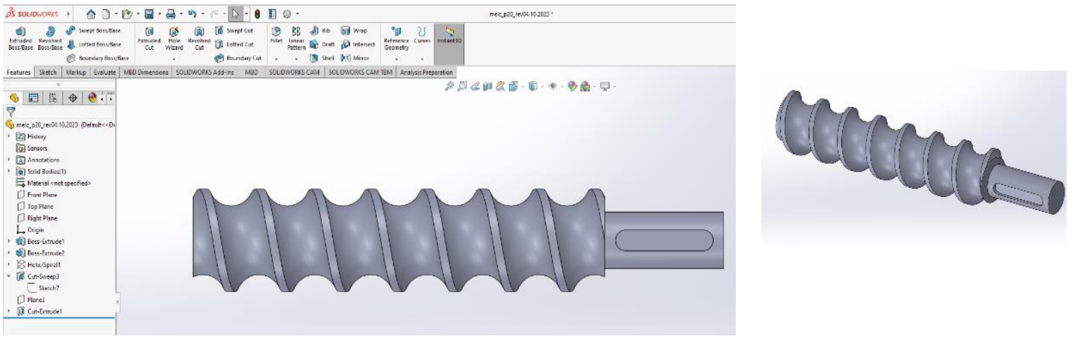


Fig.5. 5 NF 80 press screw with 22mm pitch

5.2 Analiza structurala MEF a presei cu melc NF80

The 2D simulation was used and the 3D simulation was not performed, due to the complex shape of the screw and the way the pressure acts on it. Therefore, due to the non-uniformity that the pressure has along the length of the screw, the following simplifications of the model were made:

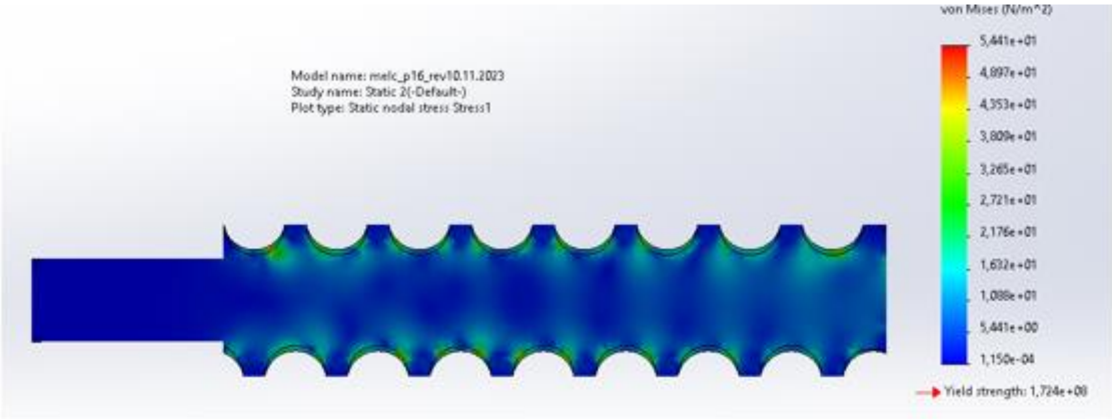
- The analysis was carried out under plane deformation conditions of the geometric model associated with the pressing screw;

- It was considered that the pressing auger is fixed/embedded at the end towards the supply area, where it receives the movement from the reducer of the oil press;

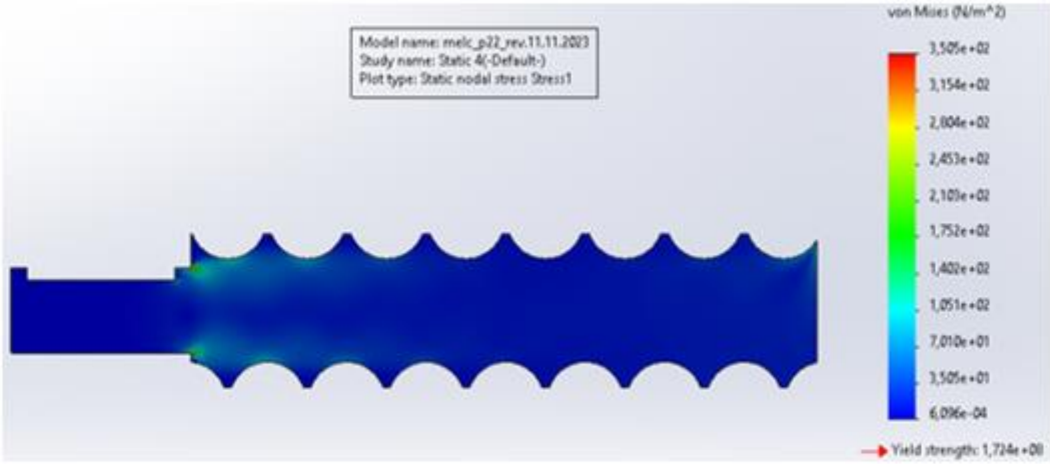
- It is considered that the snail is subjected to a pressure in the x direction, denoted by px. This pressure increases from the zero value in the feeding zone of the pressing chamber to the maximum value of 20 MPa (pmax) in the discharge zone of the sawdust from the pressing chamber; pressure increase is linear along the length of the screw;

- On each spiral of the screw, the pressure px is considered constant, but its value varies from one spiral to another, from the supply area to the exhaust area;

After the simulation, the design program provided the obtained results in graphical form; the geometric models are divided into areas of a certain color, each area comprising the region of the geometric model where the analyzed quantity has the value specified in the color legend on the right side of the screen.



a

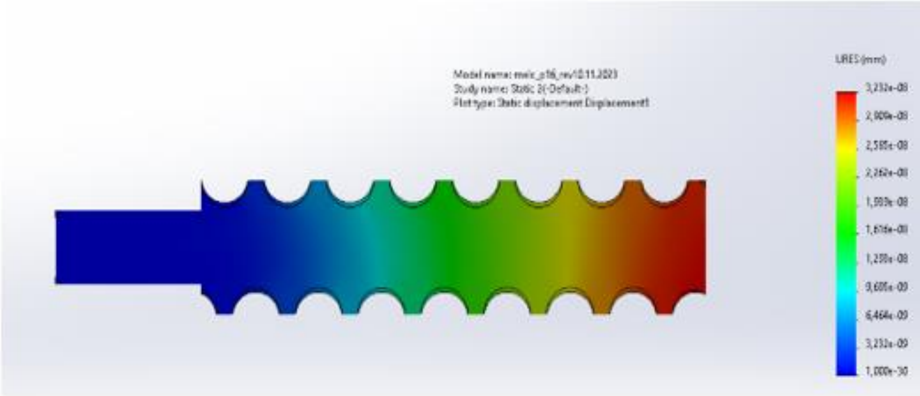


b

Fig.5. 11 The values of the equivalent stresses according to the von Mises criterion of the screw M16 (a) and M22 (b)

In fig. 5.11 shows the values of the equivalent stresses in the screw under the action of stresses, stresses calculated according to the von Mises criterion. Analyzing figure 5.11a and 5.11b, it can be seen that in the structure of the two screws there is a stress concentrator point, located in the feeding zone of the snail, the von Mises equivalent stress values created at this point being 54.4120 N/m2, for the M16 screw, respectively 350.481 N/m2.

Fig. 5.13 shows the displacement values that appear in the press screw during the previously defined stresses. Analyzing these data, it can be observed that the largest displacements of the nodes in the structure of the screw occur in the area of the discharge of the scrap, its maximum value being 3.232x10-8 mm for M16, respectively 2.630 x10-7 for M22. These displacements have smaller and smaller values the closer we get to the auger feeding area, the minimum displacements in this area being approximately 1x10-30 mm.



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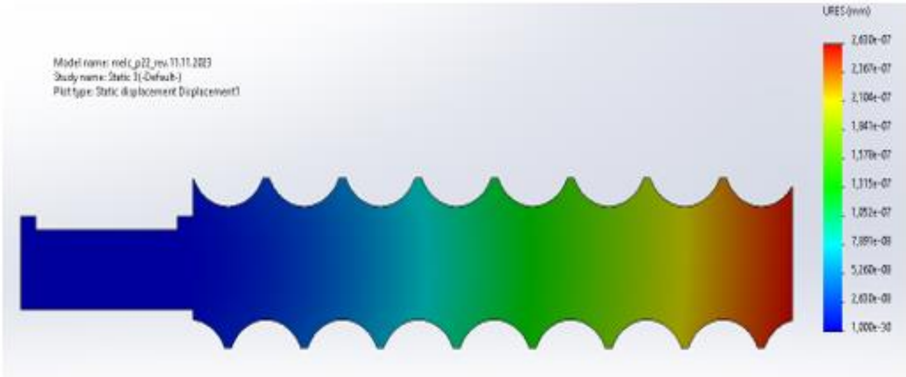


b

Fig.5. 13 Valorile deplasărilor apărute în melcul M16 (a) şi M22 (b)

CHAPTER 6
EXPERIMENTAL RESEARCH ON INCREASING THE PERFORMANCE OF A MECHANICAL PRESS FOR OBTAINING OIL FROM GRAPE SEEDS

6.1 Obtaining and conditioning grape seeds

6.1.1 Description of the place of origin of the grape seeds used for the experiments

Pomace was obtained from white grape varieties (Riesling and Fetească Regală), but also from red/black soils (Burgundy, Cabernet Sauvignon and Fetească Neagră), from two research institutes in Romania, which have viticulture as their field of activity.

From the National Research and Development Institute for Biotechnologies in Horticulture Ştefăneşti - Argeş (INCDBH Ștefănești), pomace was obtained from the varieties Riesling, Fetească Regală, Burgund and Cabernet Sauvignon. And pomace from the Fetească Regală, Riesling and Fetească Neagră grape varieties, came from the Research and Development Institute for Viticulture and Winemaking, Valea Călugărească – Prahova (ICDVV Valea Călugărească).

6.1.2 The objectives of the experimental research on the conditioning of grape seeds in order to obtain oil from grape seeds

The main objective of grape seed conditioning is to ensure as much seed purity as possible.

The specific objectives pursued in this subchapter are the following:

- determining the initial amount of residual material from grape seed varieties;
- preparation of the pomace for conditioning the seeds;
- establishing the work methodology in order to obtain the purest seeds possible;
- determination of the final amount of residues from grape seed varieties.

6.1.3 Methodology of grape seed conditioning to obtain grape seed oil

The stages of preparation of the pomace before the actual separation are as follows, fig. 6.4:

- determining the humidity of the quince; step necessary for the proper operation of the equipment to separate the seeds from the pomegranate. Usually, this range of the humidity value is specified by the manufacturer, so that the equipment functions in optimal parameters and does not clog;
- drying the pomace to a moisture value at which the separation can be carried out;
- determination of the amount of residues in the laboratory; to highlight the efficiency of the separator;
- breaking the pomace lumps resulting from the pressing of the grapes.

Transportul tescovinei | Prelevare probe | Determinarea umidității | Determinarea cantității de reziduuri din semințele de struguri

Fig.6. 4 Sampling and determination of moisture and the amount of residues

The technology used for this thesis, in order to obtain the oil from grape seeds, goes through the following stages in which the necessary equipment was used: obtaining the pomace after the winemaking process; drying the gooseberry; detaching the lumps from the pomace; separating the grape seeds from the pomace; pressing the grape seeds and finally obtaining the oil from grape seeds, fig. 6.9.

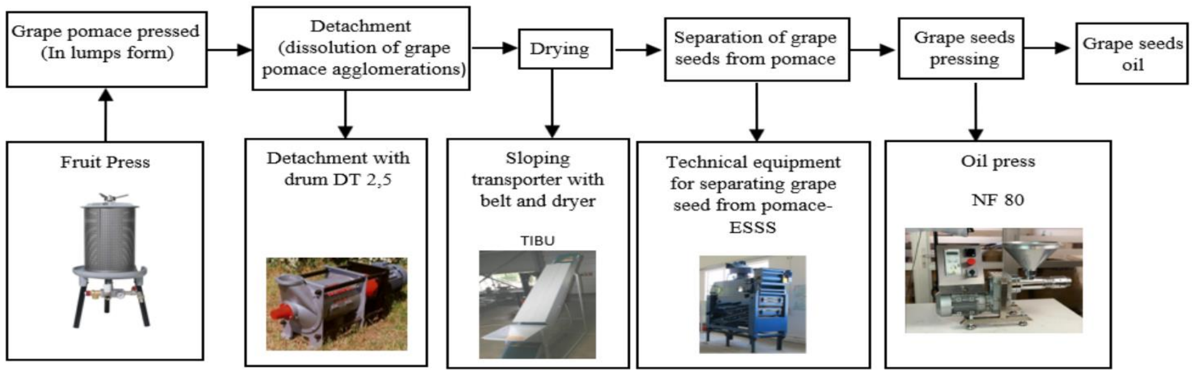


Fig.6. 9 Technology for obtaining oil from grape seeds

Regarding the separation of grape seeds from pomace, the aim was to record the material balance. This involves the introduction of a known amount of pomace into the flow, in this case it was 20 kg, following which the evacuated residues are collected from each sieve, including those sucked in by the fan and the seeds resulting at the end, which will be weighed, and the missing difference is considered a loss. The balance was carried out three times for each type of pomace, and finally the average representing the final result was made.

At the same time, an inverter was integrated into the control panel, which allowed adjusting the frequency of the motor that sets the translation system of the sieves in motion. The sieves of the separating equipment are set in motion by a roller, belt and chain system that connects all three, so it was not possible to adjust the speed of each sieve individually. Three working values at that frequency were chosen, 25, 35 and 50 Hz. The value of 50 Hz being the highest, so that the vibrations felt at the level of the entire equipment do not influence the safety of the user, but at the same time the equipment can achieve a separation of the seeds without a significant loss of them.

6.1.4 Results obtained for grape seed conditioning

The lowest humidity was found in the Burgundian lingonberry, where the initial humidity U1 was 45.25% and remains the lowest humidity until the end U3, respectively 16.33%. At the opposite pole, the highest initial humidity U1, is in the case of the pomace of the Fetească Regală 1 variety (ICSVV Valea Călugărească), respectively 62.61% and remains the highest until the separation stage, respectively U3 = 27.35%.

On a general level, natural drying decreased the humidity of the pomace by about 25%, which is a reasonable percentage, which was due to the favorable temperature conditions and a good air circulation in the room where the pomace was stored. But the disadvantage of this stage was a long period of time, which led me to apply another drying method.

In the case of artificial drying, with the help of electric drying equipment, the humidity decreased by 20%, in a much shorter period of time, in a few hours to be exact.

Given that the humidity dropped below the 30% threshold, as can be seen in fig. 6.12, it was considered to be the time to complete the next stage in order to obtain grape seeds, this being the main objective of this subchapter.

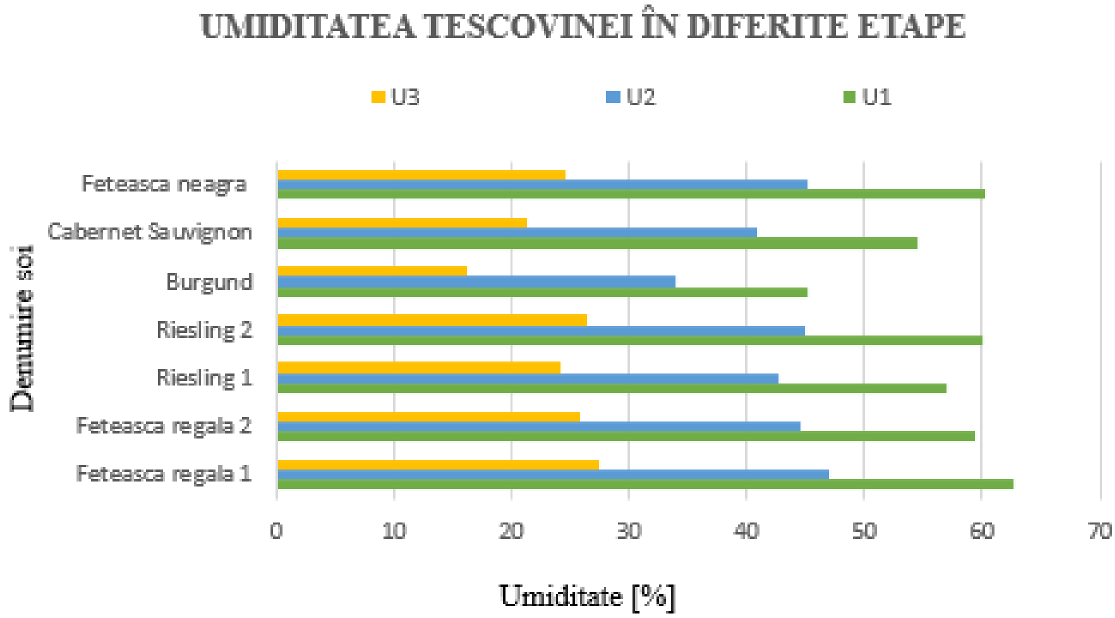


Fig.6. 12 The graph of the humidity of the pomace in different stages

At the same time, the amount of seeds present in 100g of pomace was determined in the laboratory, for each variety from which three samples were randomly taken.

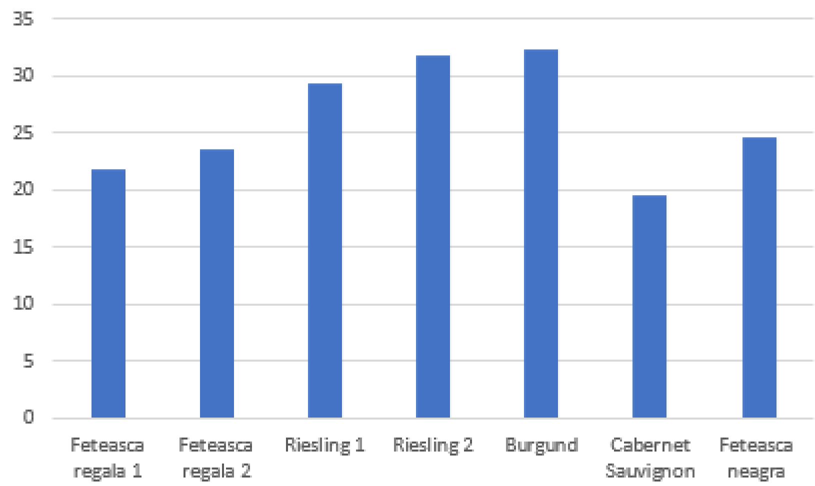


Fig.6.13 Graph of the average amount of seeds obtained from 100g of pomace

In order to better highlight the data, a pomace separation plot was created for each ESSS electric motor power supply frequency, resulting in three plots. Thus, for each variety of pomegranate, the amount of seeds obtained was highlighted in green, and in various shades of blue the refuse/residue collected from each separation stage of the equipment.

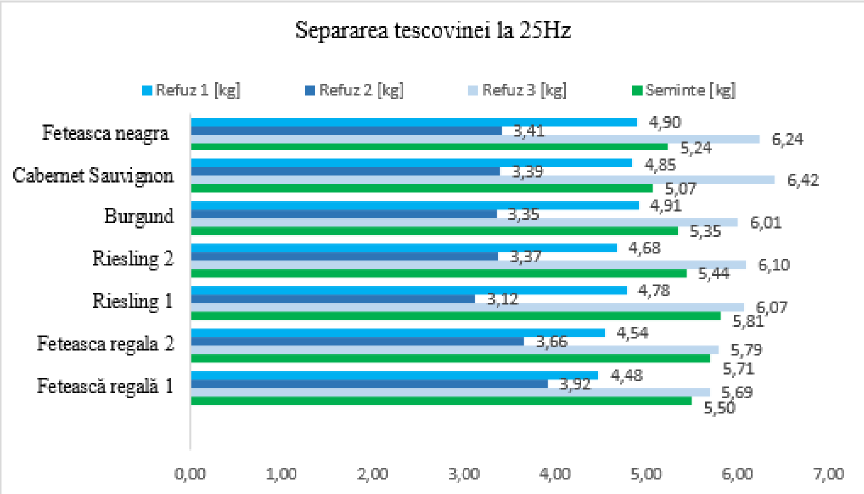


Fig.6. 15 The graph of the separation of pomace on each stage at the frequency of 25Hz of the separator motor

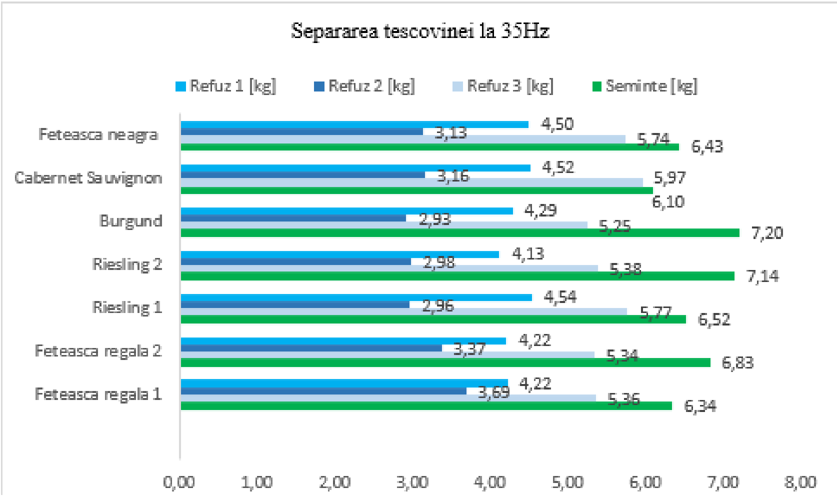


Fig.6. 16 The graph of the separation of pomace on each stage at the frequency of 35Hz of the separator motor

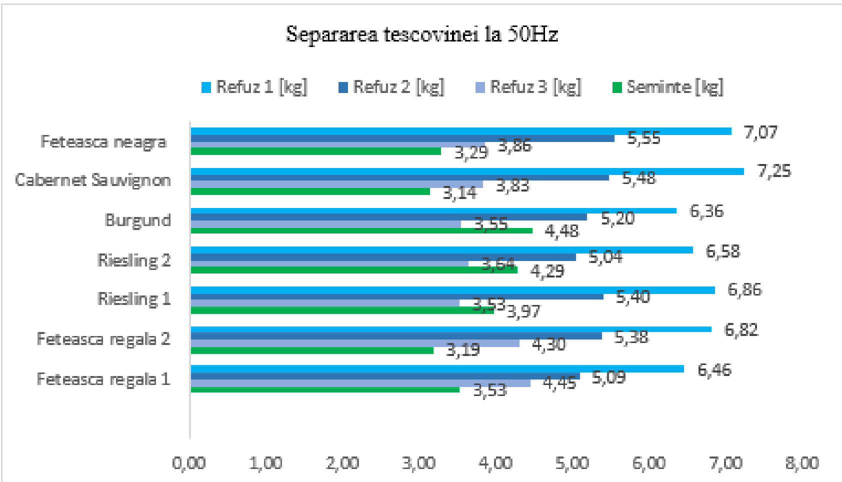


Fig.6. 17 The graph of the separation of pomace on each stage at the frequency of 50Hz of the separator motor

6.2 Experimental research on the physico-mechanical characteristics of grape seeds

6.2.1 Objectives of experimental research on the physical-mechanical characteristics of grape seeds

The main objective of this sub-chapter is the determination and study of the physical and mechanical properties of grape seeds from the varieties Riesling 1 (INCDBH Ștefănești), Fetească Regală 1 (INCDBH Ștefănești), Burgund, Cabernet Sauvignon, Fetească Regală 2 (ICDVV Valea Călugărească), Riesling 2 (ICDVV Valea Călugărească) and Fetească Neagră.

While, the specific objectives of the experimental determinations on the physical and mechanical characteristics of grape seeds are represented by:

- determination of dimensional characteristics and unit mass for grape seeds;
- determination of the average diameter and the coefficient of sphericity for grape seeds;
- determining the correlation of seed volume with their mass;
- determination of moisture content and oil content of grape seeds;
- determining the mechanical behavior of grape seeds, through uniaxial compression tests (force-deformation curves, forces and deformations at the breaking point, hardness, energy consumption at breaking).

6.2.2 Experimental research methodology, materials and equipment used

The first experimental determinations of the physical characteristics were the dimensional ones. Thus, having different varieties of grape seeds, we were able to highlight the dimensional variations between them. The samples used for the measurements were made up of 10 seeds of each variety for which the main geometric dimensions were determined with the help of an electronic caliper (fig. 6.20): L- length; l- width and b- thickness.

Fig.6. 20 Measuring grape seeds using the MAFCOM caliper

After measuring the geometric dimensions of the grape seeds, we weighed the unit mass and the mass of 1000 seeds. The weighing of the seeds was carried out with the electronic balance.

To determine the variation in the mechanical characteristics of grape seeds, the 10 seeds of each type, previously measured, were subjected to individual uniaxial compression tests between the parallel plates of the Hounsfield/Tinius Olsen mechanical testing apparatus, model H1KS. After initializing the apparatus and connecting it to the computer for data collection, baseline parameters were established and calibration was performed so that all samples were tested under the same conditions.

Fig.6. 22 Details during the grape seed pressing process

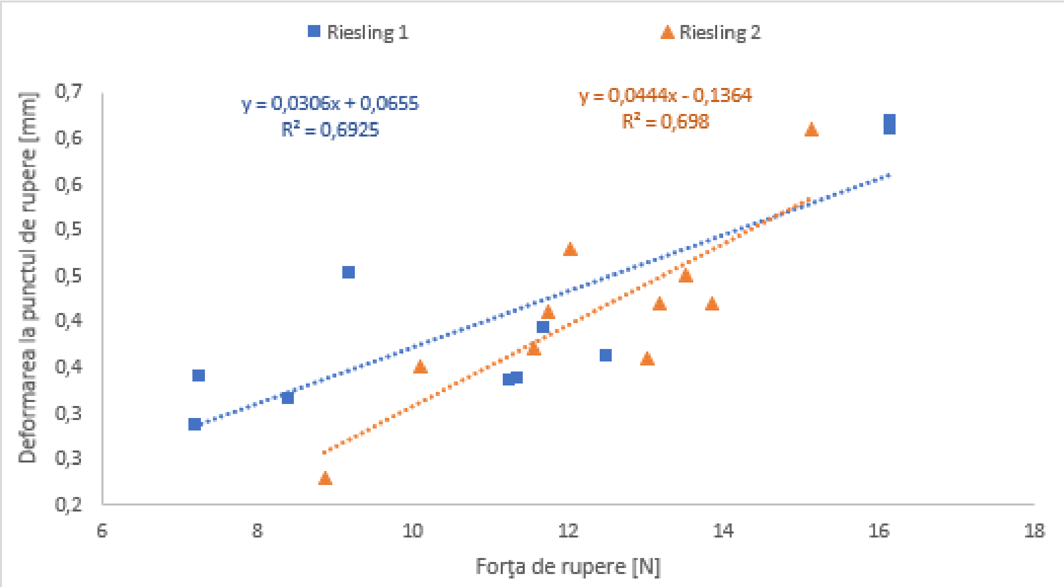
6.2.3 Results of experimental research on the physical-mechanical characteristics of grape seeds

Tabel 6. 9 Average values of physical properties of grape seed varieties

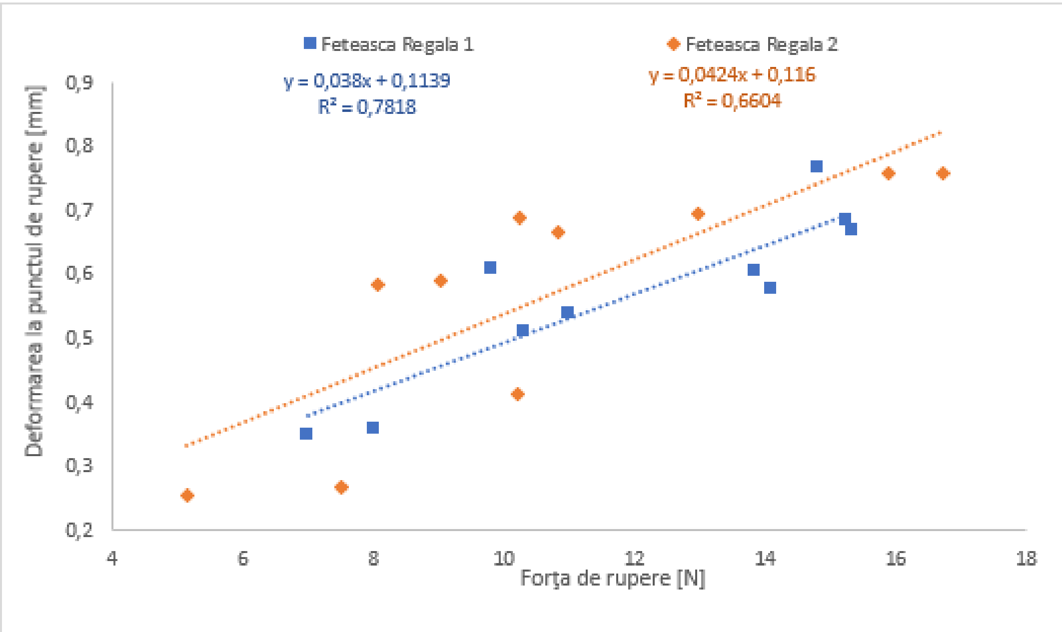
Nr. crt.	Nume soi	Dimensiunile semințelor de struguri [mm]			Masa unitara [g]	Volumul [mm^3]	Diametrul mediu [mm]	Coeficien de sfericitate	M 1000 [g]
		L-lungile	l-lățime	b-grosime					
1	Riesling 1	5,679	3,454	2,486	0,023	25,612	3,648	0,643	26,60
2	Riesling 2	5,547	3,376	2,494	0,021	24,587	3,597	0,649	27,84
3	Fetească Regală 1	5,398	3,831	2,579	0,026	27,945	3,749	0,696	29,75
4	Fetească Regală 2	5,959	3,563	2,771	0,027	30,781	3,886	0,654	34,20
5	Burgund	5,832	3,878	2,617	0,027	30,977	3,892	0,669	33,45
6	Cabernet Sauvignon	5,755	3,508	2,474	0,025	26,317	3,677	0,639	29,65
7	Fetească Neagră	5,807	3,952	2,483	0,023	30,064	3,843	0,662	25,70

In table 6.9, we calculated the average values of the physical properties of grape seeds. Thus, the highest values of the unit mass, the calculated unit volume, the average diameter, the sphericity coefficient and the mass of 1000 seeds were in the case of the seeds of the Burgundy variety, followed very closely by the seeds of the Fetească Regală 2 variety (INCDBH Ștefăneşti). At the opposite pole, the lowest values of mass and unit volume and average diameter were in the case of the seeds of the Riesling 2 variety (INCDBH Ștefăneşti) and Riesling 1 (ICSVV Valea Călugărească). The lowest value of the mass of 1000 seeds was in the case of the seeds of the Ferească Neagră variety.

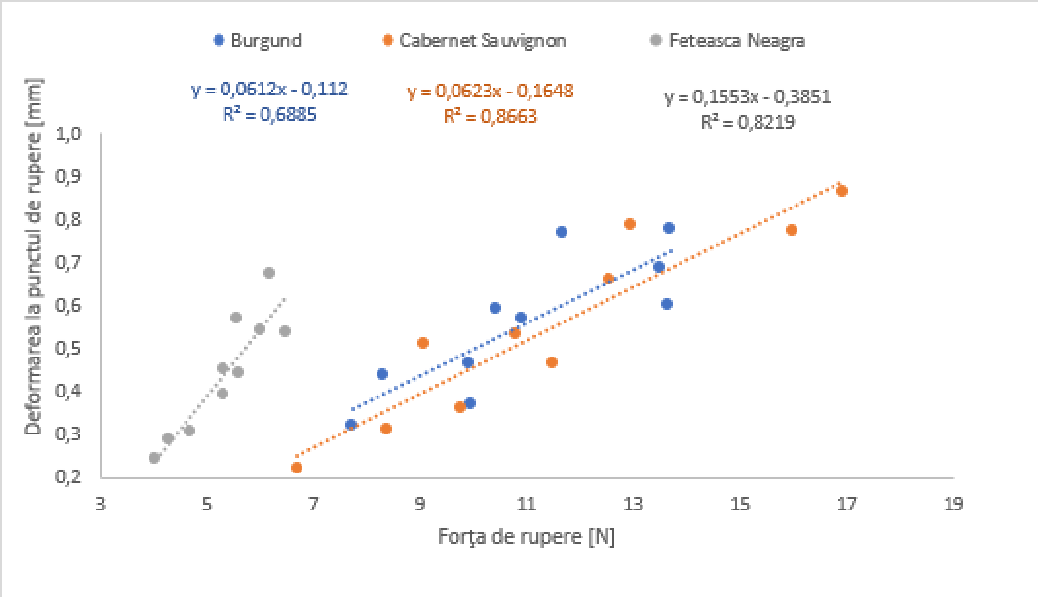
For each type of grape seed, in fig.6.30 you can find the graphs that highlight the deformation at the breaking point according to the force applied at the same breaking point.



a



b



c

Fig.6. 30 Correlation between displacement and force at breaking point of a-Riesling 1 and 2 grape seeds; b- Feteasca Regala 1 and 2; c- Burgundy, Cabernet Sauvignon and Feteasca Neagra

After determining the physical-mechanical characteristics, we also determined the moisture content, respectively the oil content of the grape seeds, which we recorded in table 6.12.

Tabel 6. 12 Conținutul de umiditate si conținutul de ulei din semințele de struguri

Nr.crt.	Nume soi	Conținut de umiditate [%]	Conținut de ulei [%]
1	Riesling 1	8,29	9,52
2	Riesling 2	7,84	10,18
3	Feteasca Regala 1	9,21	9,72
4	Feteasca Regala 2	8,75	11,46
5	Burgund	8,54	11,21
6	Cabernet Sauvignon	9,91	7,30
7	Feteasca Neagra	8,14	8,33

6.3 Experimental tests of a continuous mechanical screw press in order to increase the performance in obtaining oil from grape seeds

6.3.1 The objectives of the experimental tests of the continuous mechanical screw press

The general objective of this subchapter is to increase the performance of a screw press in order to obtain oil from grape seeds. To carry out the experiments, the components of the screw press, the mode of operation and the varieties of grape seeds were varied, so as to determine the most efficient mode by which the best yield of oil is obtained.

The specific objectives of the experimental research on obtaining oil from grape seeds using the screw press were the following:

- the experimental determination regarding the influence of the size of the scrap discharge nozzle on the amount of extracted oil;
- the experimental determination regarding the influence of the size of the scrap discharge nozzle on the material supply flow rate and the specific pressing energy;
- experimental determination of the influence of the screw pitch on the amount of oil extracted;
- determining the best yield of grape seed oil obtained.

6.3.2 Methodology of experimental tests, materials and equipment used

The experiments were carried out in the testing laboratory of the National Research and Development Institute for Machinery and Installations for Agriculture and the Food Industry - INMA Bucharest.

Screw press NF 80, fig. 6.32, manufactured in Turkey, exists within the testing laboratory of the National Research and Development Institute for Machinery and Installations for Agriculture and the Food Industry - INMA Bucharest and is a small press, respectively 710 x 260 x 550 mm and a weight of 45 kg. It has a working capacity between 1-12 kg/h and can extract the oil from several types of oilseeds, including grape seeds.

Fig.6. 32 Screw press NF 80: 1- motor; 2- control panel; 3- reducer; 4- press feeding area; 5- oil discharge area; 6- the pressing head; 7- the discharge nozzle of the meal.

In order to carry out the experiments in this paper, I established the following configuration of parameters that can be combined, so that I can determine the effects of the independent variables on the dependent variables:

- the press screw with the two variations of the pitch of 16 mm, respectively 22 mm marked with M16 and M22;

- the diameter of the nozzles with the three variations of 10, 12 and 15 mm, marked with D10, D12 and D15, respectively;

- the rotation speeds of the snail varied depending on its step; for the auger with a pitch of 16mm, we chose values such as: 10rpm, 16rpm and 22rpm, denoted by ω10, ω16 and ω22; while for the 22mm pitch screw we would select values such as: 8rpm, 12rpm and 16rpm (noted: ω8, ω12, ω16).

Tabel 6. 14 Setup experiments to extract oil from grape seeds

Configurație 1	Configurație 2
M16_D10_ ω10	M22_ D10_ ω8
M16_ D10_ ω16	M22_ D10_ ω12
M16_ D10_ ω22	M22_ D10_ ω16
M16_D12_ ω10	M22_ D12_ ω8
M16_ D12_ ω16	M22_ D12_ ω12
M16_ D12_ ω22	M22_ D12_ ω16
M16_D15_ ω10	M22_ D15_ ω8
M16_ D15_ ω16	M22_ D15_ ω12
M16_ D15_ ω22	M22_ D15_ ω16

The resulting configuration above was repeated for each variety of grape seed, namely: Riesling; Royal Maiden; Burgundy; Cabernet Sauvignon from INCDBH Ștefănești, respectively Riesling; Royal Maiden; Fetească Neagră from ICDVV Valea Călugărească. The grape seed sample was 3kg for each configuration.

6.3.3. Results of experimental tests of a continuous mechanical screw press in order to increase the performance in obtaining oil from grape seeds

Considering the fact that, for each individual configuration, tests were carried out on the seven samples of grape seeds, the graphs in fig. 6.40 and 6.41 describe the influence of the scrap discharge nozzle on the crude oil yield obtained and on the amount of filtered oil (without solid residues), for the configuration M16_ ω10. As can be seen, for each variety, polynomial equations of the second degree are obtained, which highlight a direct relationship of the influence of the nozzle.

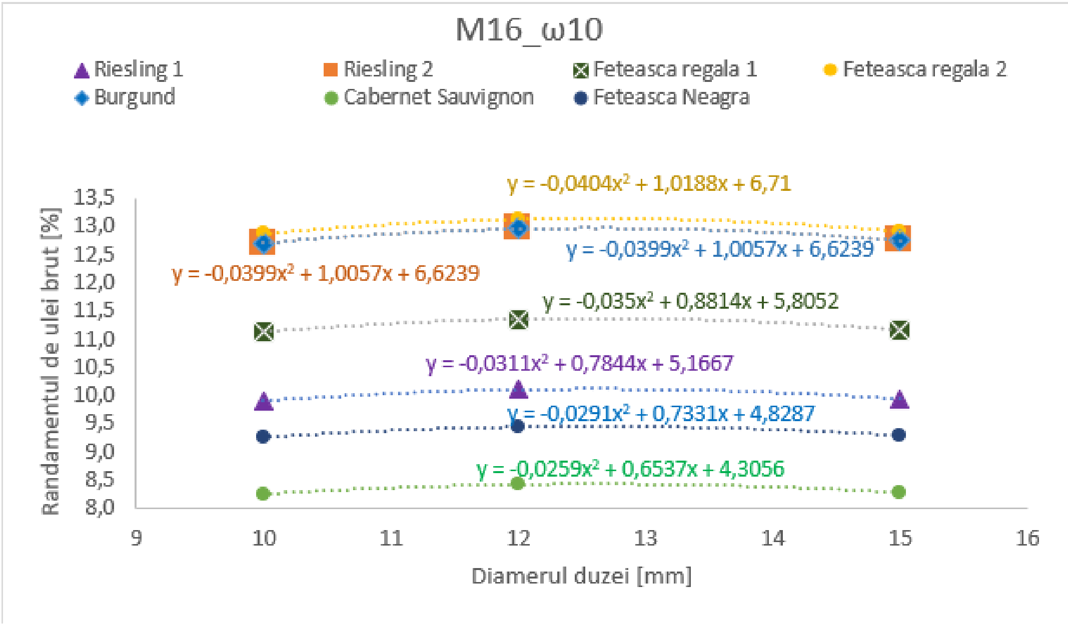


Fig.6. 40 Influence of pomace discharge nozzle on crude oil yield for each grape seed variety at M16_ ω10

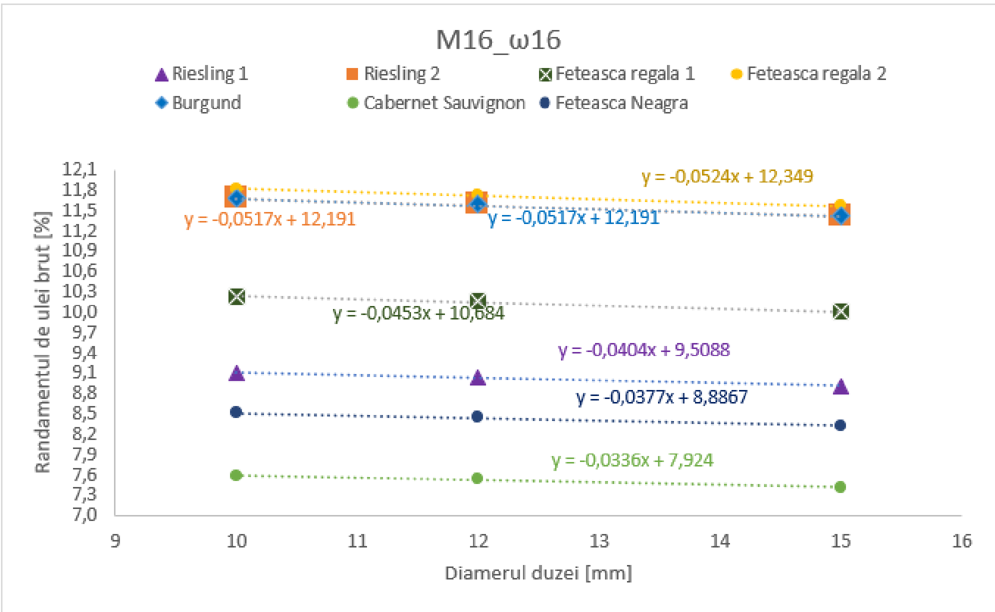


Fig.6. 43 Influence of pomace discharge nozzle on crude oil yield for each grape seed variety at M16_ω16

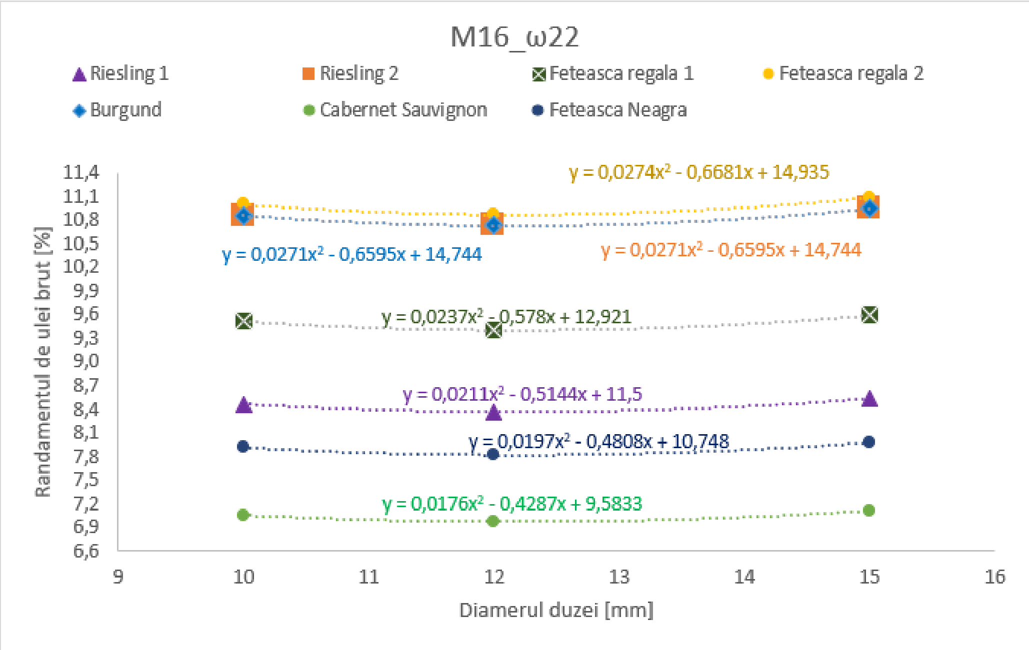


Fig.6. 46 Influence of pomace discharge nozzle on crude oil yield for each grape seed variety at M16_ω22

It is observed that the maximum values obtained, for all efficiency parameters, were obtained when the nozzle had the largest diameter of 15 mm. This is also due to the increase in the speed of the screw from 16 rpm to 22 rpm, which increases the flow of material fed, and a diameter of the nozzle facilitates the discharge of the scrap so that it does not block.

Compared to the previous configurations M16_ ω10 and M16_ ω16, for the configuration M16_ ω22 the lowest values of the monitored efficiency parameters are observed.

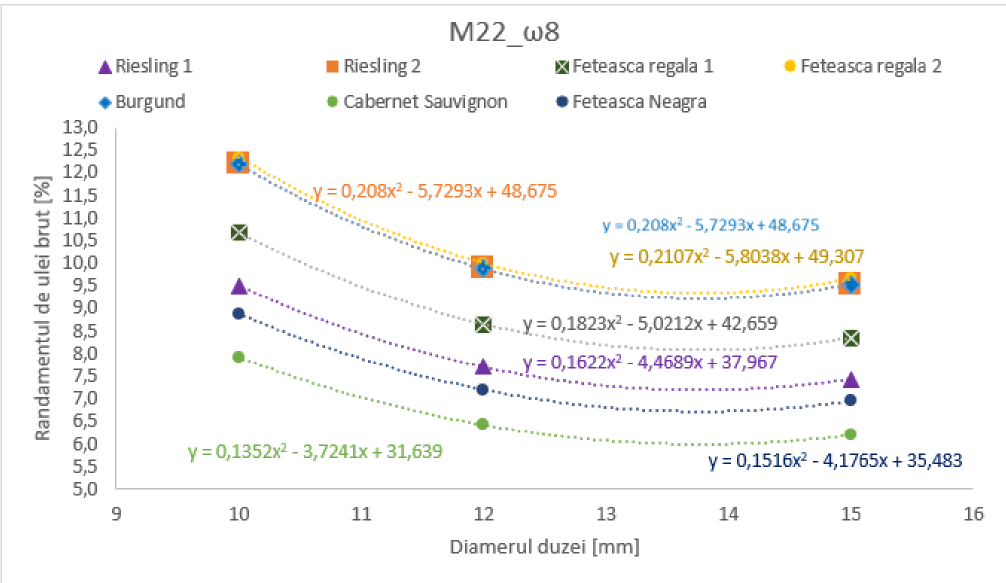


Fig.6. 49 Influence of pomace discharge nozzle on crude oil yield for each grape seed variety at M22_ω8

In fig. 6.49, 6.50 and 6.51 are the graphical representations of the influence of the pomace discharge nozzle on the yield of crude oil obtained for each grape seed variety at the configuration of M22_ω8, M22_ω12 and M22_ω16.

The crude oil yield for the M22 screw configuration is lower than the values obtained for the crude oil yield obtained for the M16 screw configuration.

The lowest crude oil yield obtained was in the case of the M22_ω16 configuration with a nozzle diameter of 15 mm, where the values fell below 5%.

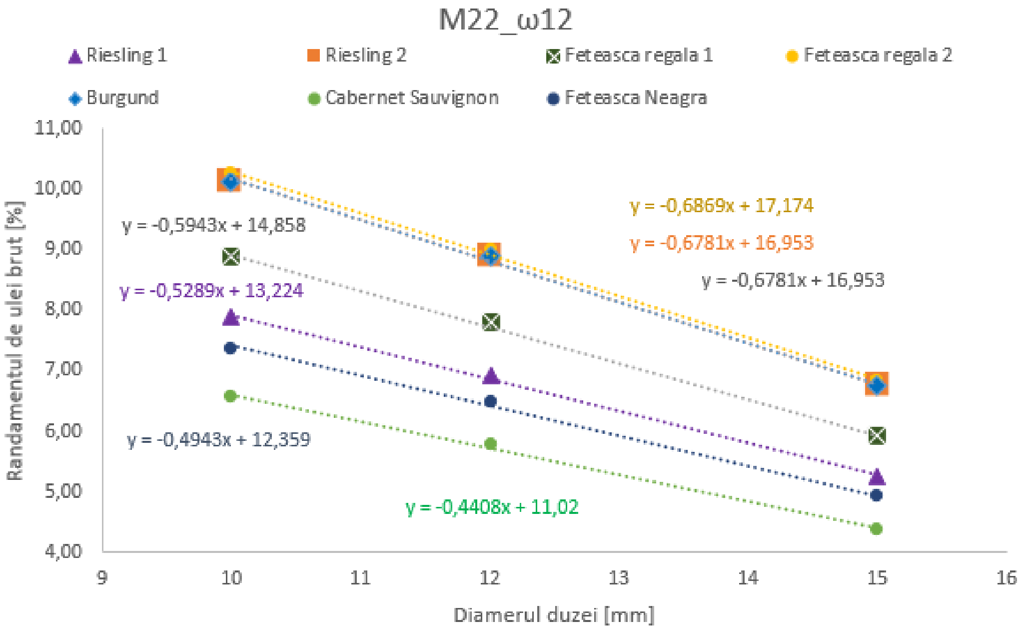


Fig.6. 50 Influence of pomace discharge nozzle on crude oil yield for each grape seed variety at M22_ω12

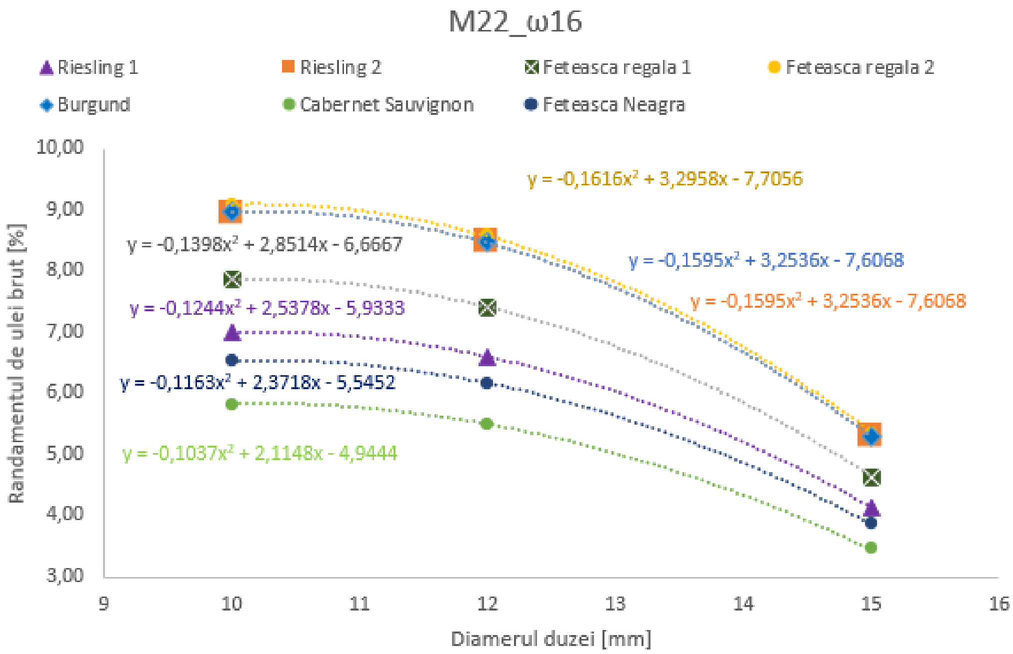


Fig.6. 51 Influence of pomace discharge nozzle on crude oil yield for each grape seed variety at M22_ω16

In fig. 6.55 and 6.56 show the graphs showing the influence of speed on crude oil yield and extracted oil efficiency for all configurations from M16. It is observed that the best results were obtained when the speed of the screw was the lowest, namely 10 rpm, and with their increase, the yield of crude oil and the efficiency of extracted oil decreased drastically.

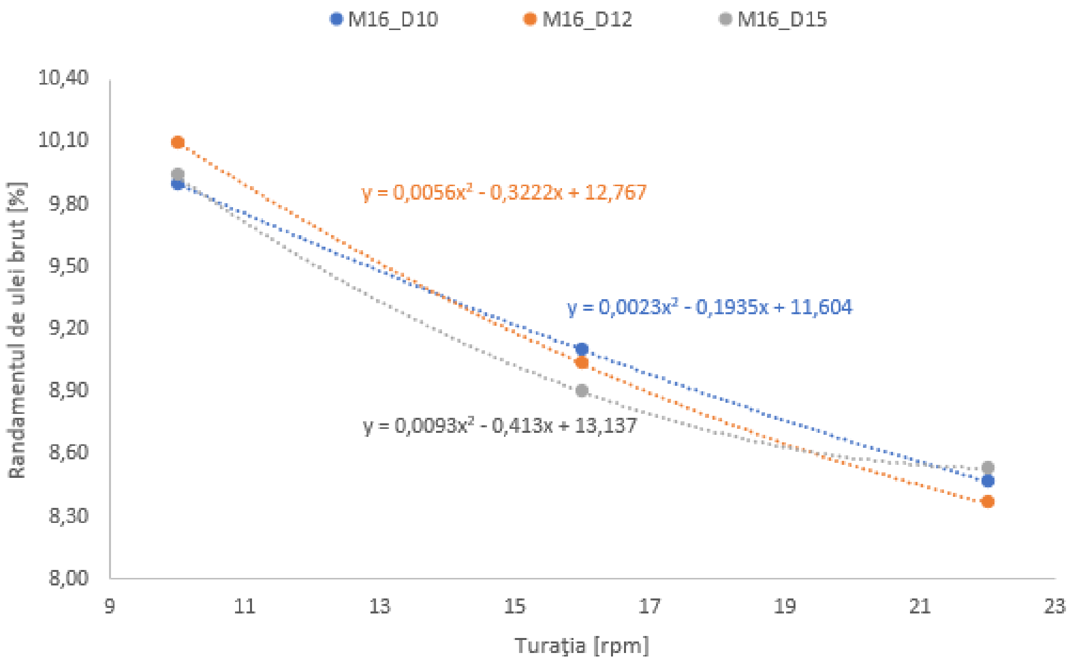


Fig.6. 55 Influence of rpm on crude oil yield for each configuration at M16

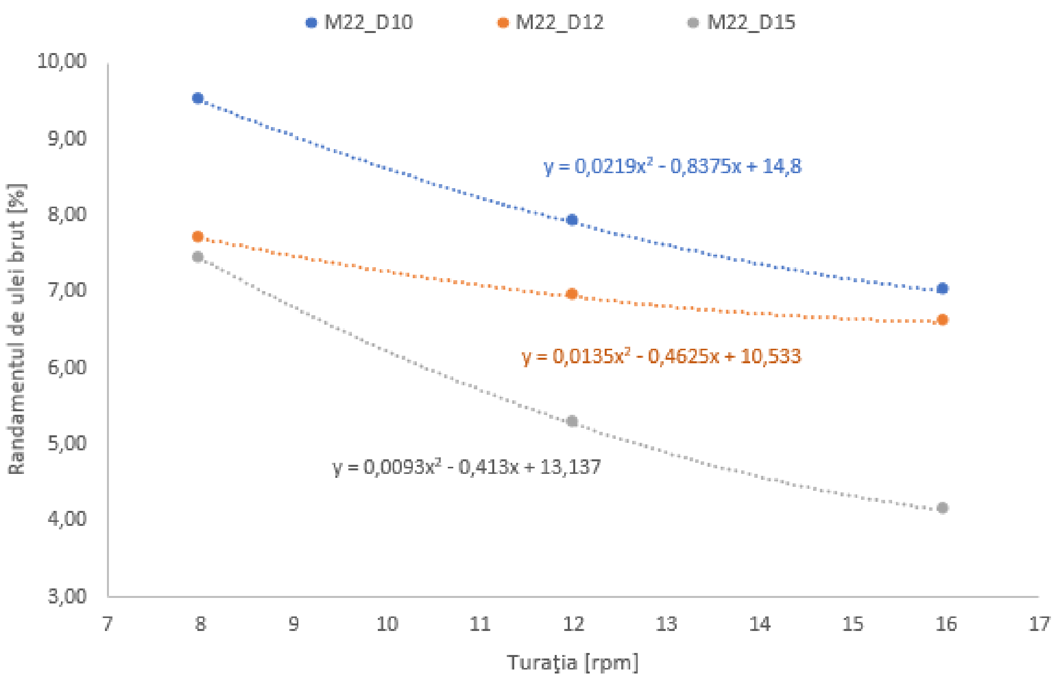


Fig.6.57 Influence of rpm on crude oil yield for each configuration at M22

In fig. 6.57 and 6.58 are the graphs showing the influence of speed on the yield of crude oil and on the efficiency of extracted oil for all configurations from M22. It is observed that the best results were obtained when the screw speed was the lowest, respectively 8 rpm, and with their increase, the value of crude oil yield and extracted oil efficiency decreased drastically.

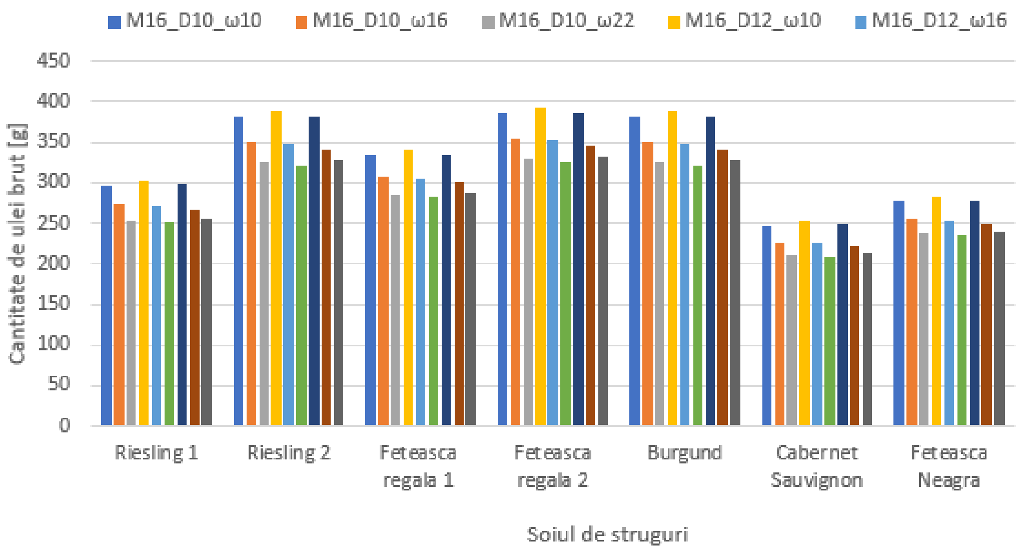


Fig.6. 59 The influence of the grape variety on the amount of crude oil extracted at M16

In fig. 6.59 and 6.60 the amount of crude oil obtained for each variety of grape seeds for which experimental research was carried out is represented graphically. Also shown are the associated configurations for which these results were obtained.

Regarding the distance between the spirals of the auger, both in fig. 6.59 and 6.60, as well as in the figures above, it is obvious that in the configurations where the auger has a smaller distance, respectively of 16 mm, the most good results in terms of efficiency parameters. At the opposite pole, the configurations where the distance between the turns is 22 mm led to the lowest values of the efficiency parameters.

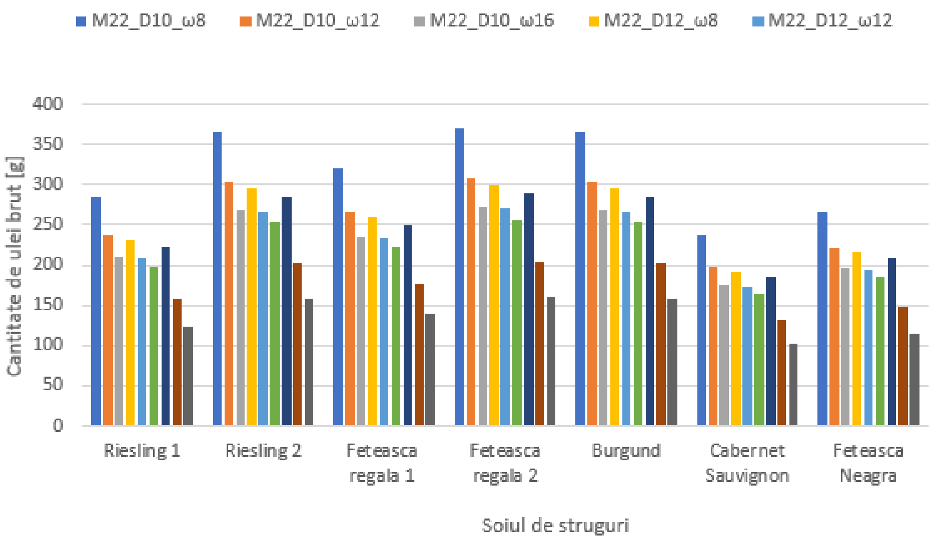


Fig.6. 60 influence of grape variety on the amount of crude oil extracted at M22

CHAPTER 7

GENERAL CONCLUSIONS. CONTRIBUTIONS. PERSPECTIVES

7.1 Conclusions regarding theoretical and experimental research

Following the careful analysis of the theoretical and experimental research carried out in this doctoral thesis, the following general conclusions can be drawn:

1. At the international level, but also in Romania, the tendency to protect the environment and treat waste responsibly leads to the generation of new by-products from agro-food waste.
2. Pomace is an agro-food waste generated in the wine and grape juice production industry, from which a variety of alternative food and non-food by-products can result, such as flour, grape seed oil, compost, biomass, antioxidant extracts, extracts of proteins, extracts on polyphenols and sugars, etc.
3. Grape seeds, an important component of the gooseberry, from which oil can be extracted, but also other nutrients used in fields such as pharmaceutical, food, chemical, agricultural, etc.
4. Grape seed oil is edible and contains an important source of antioxidants, it also has an anti-inflammatory, antimicrobial role, contributes to improving the immune system and has dietary activity.
5. Extraction of grape seed oil can be done by various methods such as: chemical extraction, supercritical fluid extraction, steam distillation, mechanical extraction. However, each of these methods has advantages and disadvantages and can be selected depending on the specific characteristics of the raw material, the quality of the desired oil and the production requirements.
6. Studying the physical-mechanical properties of grape seeds (average diameter, weight of 1000 seeds, moisture content, volume, sphericity coefficient, compressive strength) is important for choosing the constructive and functional parameters of mechanical presses, but also of the flow technological in general.
7. Analyzing the specialized literature, it can be concluded that the parameters with the most significant influence on the pressing process of oleaginous materials include the following: the temperature of the pressing chamber, the speed of the screw, the size of the discharge hole of the sawdust, the level of pressure applied to the material, the duration of the pressing process pressing, the feed rate of the material to be pressed, the temperature of the oleaginous material, the moisture content of the raw material and the percentage of shell in its composition.
8. The mathematical modeling of the estimated working capacity was carried out according to the characteristics of the screw press, of the compression ratio of the material inside the press chamber and of the power required to drive the screw press in chapters 4.6.1 and 4.6.2.
9. In order to highlight the increase in the performance of the screw press used in the experiments in chapter 6, the following coefficients related to the efficiency of the process were established: the yield of oil obtained, the efficiency of the extraction of oil from grape seeds,

the efficiency of the material balance and the losses of material, which can be found in subsection 4.6.3.

10. Other mathematical models have been proposed that describe the influence of the press parameters such as the diameter of the exhaust nozzles, the feed flow rate, the power required to actuate the press on the oil yield, in subchapter 4.6.4.

11. In order to model the screw press process using the finite element method, it is essential to have a thorough understanding of the physico-mechanical properties of the oleaginous material as well as the characteristics of the press used. At the same time, this process involves the adoption of some simplifying assumptions necessary for the simulation, but they do not cover all the real aspects that appear during the pressing process.

12. Following the MEF simulation of the two screws with a distance between turns of 16mm and 22mm respectively, in the SolidWorks Simulation program, values for the displacements, equivalent stresses and deformations occurring during the pressing process could be obtained. Comparing the values obtained, it was concluded that the values of displacements and stresses for the auger with the larger pitch were higher than for the auger with the smaller pitch.

13. Also, a MEF study was carried out for a grape-picking Saturday when applying a force in a vertical position and in a horizontal position. Comparing the values obtained for the displacements and stresses appearing inside the seed, it was concluded that the values for the horizontal positioning of the seed are higher than in the vertical position.

14. Due to the lack of pomace processors in Romania, it was inevitable to collect pomace from the wine producing partners INCDBH Ștefănești-Argesi and ICDVV Valea Călugărească-Prahova, for the extraction of grape seeds. Thus, the quince was obtained from the grape varieties Riesling, Fetească Regală, Burgund, Cabernet Sauvignon from INCDBH Ștefănești, respectively Riesling, Fetească Regală and Fetească Neagră from ICDVV Valea Călugărească.

15. In subchapter 6.1.3, a methodology and a technology that serve the right purpose for the extraction of grape seeds from mulberry have been created.

16. The influencing factors on the separation process were the humidity and the amount of grape seeds in the pomace. In order to reach a humidity at which the equipment to be separated has a good yield, two stages of drying were completed so that from the initial average humidity of approximately 56.97%, it was reduced in the first stage of natural drying by approx. 25%, and in the second stage (drying with the Electric Dryer equipment) with approx. 20% Finally, for each variety of grapes the humidity dropped below 30%, at which the separation equipment works in optimal parameters, with a general average of 23.7%.

17. The general average quantity of grape seeds from the gooseberry determined in the laboratory was 26.17g from 100g of gooseberry, while the amount of seeds extracted with the separation equipment in the best operating mode was 6.65 kg from 20kg of pomace, representing 33.25%.

18. After determining the dimensional characteristics of the seeds, it was concluded that there are differences both for seeds of the same variety and for different varieties. This is explained, not only by the differences in variety, but also by the different degree of development of each individual grape and by the pedo-climatic conditions in which the vine developed.

19. To determine the mechanical properties related to the compressive strength of grape seeds, uniaxial compression tests were carried out, which is the most used method and with the

help of which force-deformation curves are obtained, from which important information is obtained regarding force, deformation and the energy consumed at the breaking point of the grape seeds, respectively the maximum force and deformation.

20. Following the compression tests, the correlation between the deformation and the force at the breaking point of the grape seed of each variety studied was established. From which it resulted that the highest correlation existed for the seeds of the Cabernet Sauvignon and Fetească Neagra varieties.

21. For the grape seeds subjected to compression tests, it was determined that the force applied to break was different from one variety to another: Riesling 1 (ICDVV Valea Călugărească) 11.11N; Riesling 2 (INCDBH Stefanesti) 12.30N; Feteasca Regală 1 (ICDVV Valea Călugărească) 11.94N; Feteasca Regală 2 (INCDBH Ștefănești) 10.66N; Burgundy 10.98N; Cabernet Sauvignon 11.46N; Fetească Neagră 5.35N. The overall average being 10.54 N.

22. Two very important parameters related to the characteristics of grape seeds are moisture and oil content. These were determined in subchapter 6.2.3 and different values were obtained for each grape seed variety. However, a general average of the moisture content was 8.67%, and for the oil content the general average was 9.67%, these being comparable to those in the specialized literature.

7.2. Personal contributions

The original contributions arising from this PhD thesis are as follows presented in summary:

1. The synthetic analysis of the specialized literature regarding the current state of theoretical and experimental research in the field of grape seed pressing process was carried out by consulting 150 specialized works published domestically and internationally. This exhaustive assessment of the relevant source of information has enabled a thorough understanding of recent advances and emerging trends in this field.

2. The development of two mathematical models for estimating the power required to actuate screw presses, the first being based on the calculation of the power components, and the second being made by analogy with the mathematical model from the actuation of a screw with a helical thread (when only the nut moves axially which meets some resistance).

3. Proposing mathematical models for expressing the degree of oil extraction according to different functional parameters of the process, both in screw presses.

4. Using the finite element method (in the SolidWorks program) for modeling and simulating the mechanical behavior of two snails with different distance between turns and of a wave of grape seeds in vertical and horizontal position.

5. Carrying out some experimental research in order to determine certain physical characteristics (average diameter, weight of 1000 seeds, moisture content, volume, sphericity coefficient) of grape seeds and interpretation of the obtained results.

6. Carrying out experimental research regarding the determination of the mechanical characteristics of grape seeds, by performing uniaxial compression tests between parallel flat plates and highlighting the behavior of the seeds under these types of stresses.

7. Carrying out experimental research regarding the determination of the influence of the size of the outlet of the pomace on the efficiency parameters of the pressing process for the varieties of grape seeds studied.

8. Carrying out experimental research regarding the determination of the influence of the distance between the spirals of the snail and the variety of grape seeds on the yield of extracted oil.

9. Carrying out experimental research regarding the determination of the influence of the screw speed on the efficiency parameters of the pressing process for the varieties of grape seeds studied.

10. The results obtained in the studies and research carried out within the thesis were capitalized by the elaboration and publication of a number of 14 scientific works in specialized magazines, in the volumes of national and international conferences and their presentation in national and international scientific events, in as author and co-author (of which 4 are ISI indexed).

7.3. Perspectives

1. The grape seed conditioning methodology and technology is relatively new, therefore more experimental research is needed to make the process of obtaining grape seeds more efficient.
2. 3D simulations can be performed for the entire pressing process, from the feeding to the evacuation of the grape seeds, if there is access to more advanced simulation programs.
3. In order to better understand the grape seed pressing process, it is recommended to install some sensors in the future to measure the pressure in the pressing chamber in real time.
4. Experimental tests can be carried out with other configurations of the match press such as other variations of the screw (conical screws, screw with constant diameter and different pitch, with different diameter and pitch, etc.), but also with other variations of the chamber pressing (cylindrical pressing chamber with different outlet hole diameter).
5. Experimental tests can be carried out with crushed grape seeds before pressing them. At the same time, shredding can be done with different granulometry.

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26. * * * programul CAD SolidWorks
27. * * * programului de analiză cu elemente finite SolidWorks.

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Period	01.10.2017–present
The name and type of the educational institution and the professional organization through which the professional training was carried out	Polytechnic University of Bucharest, Faculty of Biotechnical Systems Engineering
Field studied / occupational skills	Research on increasing the performance of an equipment intended to obtain oil from grape seeds
Type of qualification / diploma obtained	PHD

The level of classification of the form of training/education in the national or international system	Higher Education
Period	01.10.2015–29.07.2017
The name and type of the educational institution and the professional organization through which the professional training was carried out	Politehnica University of Bucharest, Faculty of Biotechnical Systems Engineering - Research, Design and Testing of Biotechnical Systems
Field studied / occupational skills	- Computer-aided design - SolidWorks; - Project Management; - Dynamics of biotechnical systems;
Type of qualification / diploma obtained	Master
The level of classification of the form of training/education in the national or international system	Higher Education
EDUCATION AND TRAINING	
Period (from – to)	01.10.2011–29.07.2015
The name and type of the educational institution and the professional organization through which the professional training was carried out	Polytechnic University of Bucharest, Faculty of Biotechnical Systems Engineering
EDUCATION AND TRAINING	-Material resistance; -Mechanics; - Installations and systems for Environmental Protection; -Hydraulics; -Computer-assisted design-Solidworks;
Tipul calificării / diploma obţinută	Bachelor – Engineer
Nivelul de clasificarea formei de instruire/ învăţământ în sistemul naţional sau internaţional	Higher Education
PERSONAL SKILLS AND COMPETENCES	• *• Course - SOLIDWORKS Essential – CADWORKS Certificate* • *• Course - SOLIDWORKS Simulation (Static, Professional, Flow) – CADWORKS Certificate* • *• Course - Auditors of the Quality Management System in an accredited laboratory/in the process of accreditation according to SR EN ISO/IEC 17025:2018 and SR EN ISO 19011:2018 standards - Fiatest*
Mother tongue(s)	Romania
Foreign language(s) known	ENGLISH
the ability to read	Good
the ability to write	Good

the ability to speak	Good
Artistic skills and competences	- Photography - Photo editing: Lightroom; Photoshop.
Skills and competences and sociable	- Critical thinking, - Creativity, - Flexible and adaptable, - Motivated, - Ability to solve problems.
Organizational skills and competences	- Organization of delegations from several projects (trips for experimentation, trips to events and lectures, trips to fairs)
Skills and technical competences	Solidworks, Microsoft Word, Microsoft Excel, Microsoft PowerPoint, Outlook 365, Design Expert.
Driver's license(s)	YES
Other skills and competences	- Ability to work under stress; - Team work.
Additional Information	

Date: 28.11.2023 **ing. VASILACHI (BĂLȚATU) Carmen**

List of works in the field of doctoral thesis

1. **Vasilachi C.,** Biris S. S- Study concerning technologies for obtaining oil from grape seeds, 7th **International Conference on Thermal Equipments, Renewable Energy and Rural Development (TE-RE-RD 2018),** ISSN 2359 – 7941, ISSN-L 2359 – 7941, *http://www.tererd.pub.ro/wp-content/uploads/2018/07/Proceedings-TE-RE-RD-2018-tiparit.pdf*
2. **Vasilachi C.,** Biris S. S.- Modelling by finite element method of the twin-screw of a press for obtaining grape seed oil, **8th International Conference on Thermal Equipments, Renewable Energy and Rural Development (TE-RE-RD 2019),** E3S Web Conf, Vol. 112, *https://doi.org/10.1051/e3sconf/201911203022* **WOS:000619989000055**
3. **Baltatu, C.,** Paun, A., Biris, S.S., Anghelache, D. AND Mateescu, M., **2022.** Methodology for conditioning grape seeds to obtain the oil, **ENGINEERING FOR RURAL DEVELOPMENT,** Jelgava, 25.-27.05.2022. *DOI: 10.22616/ERDev.2022.21.TF282*
4. Cristea O., Catana L., Bracacescu C., **Baltatu C.,** Vladutoiu L., Grigore I., Ungureanu N.- Processing methods of wine by-products to obtain grape seed oil and grape seed flour as functional ingredients for food fortification, 48th **Symposium "Actual Tasks on Agricultural Engineering"**, Zagreb, Croatia, 2021, ISSN 1848-4425, http://atae.agr.hr/48th_ATAE_proceedings.pdf **WOS:000664133000047**
5. **Vasilachi C.,** Biris S. S. - Research on the extraction methods of grape seed oil / Cercetări privind metodele de extracție a uleiului din semințe de struguri, **International Symposium ISB-INMATEH 2018,** ISSN 2344 – 4118, ISSN-L 2344 – 4118; *http://isbinmateh.inma.ro/archive.html*
6. **Vasilachi C.,** Biris S. S.- Synthesis of the theoretical and experimental research on the technologies for obtaining grape seed oil, **2019**, vol. 1, pag. 316-320, Lozenec, Bulgaria; ISSN 1313-7735, *http://conf.bionetsyst.com/wp-content/uploads/2019/12/Volume1-Lozenec-2019.pdf*
7. **Vasilachi (Bălțatu)** C., Biriș S. Șt., Gheorghiță E., Gheorghe G., Mateescu M.- The study of innovative models of screw presses which can obtain a higher yield of grape seed oil – a review, **International Symposium ISB-INMATEH 2019,** ISSN 2537 – 3773, ISSN-L 2344 – 4118, *http://isbinmateh.inma.ro/archive.html*
8. **Vasilachi (Baltau) C.,** Biris S., Mateescu M., Gheorghe G.- Determination of the longitudinal modulus of elasticity for the different type of grape seeds, **International Symposium ISB-INMATEH 2020,** ISSN 2537 – 3773, ISSN-L 2344 – 4118, *http://isbinmateh.inma.ro/archive.html*
9. **Bălțatu C.,** Milea D., Păun A., Biriş S.Şt., Vlăduţoiu L., Grigore A.I.**-** Using an equipment with vibrating sieves for separation of grape seeds from marc**, International Symposium ISB-INMATEH 2021,** ISSN 2537 – 3773, ISSN-L 2344 – 4118, http://isbinmateh.inma.ro/archive.html
10. **Bălțatu C.,** Mateescu M., Anghelache D., Tăbăraşu A-M.- The importance of moisture in extracting oils from oilseeds - a review, International Symposium **ISB-INMATEH 2021**, ISSN 2537 – 3773, ISSN-L 2344 – 4118, http://isbinmateh.inma.ro/archive.html
11. **Balţatu C.,** Biris S.S., Marin E., Mateescu M., Gheorghe G., Manea D., Ion M., Grape seeds processing technology and methodology, **International Symposium ISB-INMATEH 2022**, ISSN 2537 – 3773, ISSN-L 2344 – 4118, http://isbinmateh.inma.ro/archive.html

12. **Bălţatu C.,** Biris S.S., Marin E., Mateescu M., Gheorghe G., Manea D., Matache G., Design and stress analysis of the screw of the mechanical press to obtain grape seed oil, **International Symposium ISB-INMATEH 2022**, ISSN 2537 – 3773, ISSN-L 2344 – 4118, http://isbinmateh.inma.ro/archive.html

13. **Vasilachi (Baltăţu) C.,** Biriş S.S. and Gheorghe G.- Study of the compression behavior of grape seeds using the Finite Element Method, **9th International Conference on Thermal Equipments, Renewable Energy and Rural Development (TE-RE-RD 2020)**, E3S Web Conf, Volume 180, *https://doi.org/10.1051/e3sconf/202018003017*

14. **Carmen BĂLȚATU,** Sorin-Ștefan BIRIȘ, Marianela MATEESCU, Eugen MARIN, Gabriel GHEORGHE- Determination of the main properties of grape seeds and improving the mechanical oil extraction, **U.P.B. Sci. Bull., Series D, Vol. 85, Iss. 2, 2023, ISSN 1454-2358,**https://www.scientificbulletin.upb.ro/SeriaD_-_Inginerie_Mecanica.php?page=revistaonline&a=2&arh_an=2023&arh_ser=D&arh_nr=2