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MECHANICAL CONTINUOUS OIL EXPRESSION FROM OILSEEDS: OIL YIELD AND PRESS CAPACITY

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Abstract: *Oil can be obtained from an oil seed through mechanical methods or solvent extraction. Mechanical expression of oil involves the application of pressure (using hydraulic or screw presses) to force oil out of the oil bearing material. In solvent extraction, solvent such as hexane is usually applied to remove oil from the material. Mechanical expression or mechanical pressing is, however, preferable due to the fact it is economical compared with the solvent process. At the laboratory scale, many authors have highlighted the effect of operating parameters and raw material on process performance (oil yield and press capacity).*
Keywords: *mechanical expression, oil yield, press capacity, screw pres, process performance*

1. INTRODUCTION

Vegetable oils are one of the oldest classes of chemical compounds known to mankind and even the famous Homer concerned himself with the use of vegetable oils [16]. Numerous references and clues are found that indicate the use of these oils during stone age and bronze age. During the Egyptian times, the sesame plant had a mythical status. In certain ceremonies, black sesame seeds were used to represent problems and regrets and were ritually burned. Nowadays, the view on oilseeds and oils is slightly more down to earth: the oils are used in food, paint and the market for renewable fuels is growing rapidly. World market for oils and fats is approaching 400 million metric tons of seed produced every year, resulting in a total amount of oil of around 100 million ton [16].
The oleaginous raw materials are numerous and most varied. Of more than 110 species of oleaginous plants, on the world market there are presently about 50, grouped in 15 important botanical families [3], [9], namely: compositae (sunflower), cruciferae (rape), leguminous plants (soya), malvaceae (cotton), papaveraceae (poppy), rozaceae (almond tree, hazel tree), peduliaceae (sesame), vitaceae (grape seed), jugladaceae (nut tree), palmae (oil palm, coconut palm, palm kernel), foleaceae (olive tree), linaceae (flax), cucurbitaceae (pumpkin seeds) leufobiaceae (castor oil plant) and solanaceae (tomato seeds, tobacco seeds) [9].
Due to their particular importance, oleaginous plants are being grown worldwide, the extent of each culture depending on the geographical area. Thus, if on a worldwide scale the palm tree holds the top position among the oleaginous raw materials, with 28.6% of the world vegetable oil production, in Europe, sunflower is ranked first, with 34.1% of the oil production, being closely followed by rape, with a share of 33.3%. In Romania, the mainly grown oleaginous plant is sunflower, with 76% of the domestic vegetable oil production. As far as the areas under cultivation are concerned, in 2013 Romania was ranked first among the EU member states; however, the average yield per hectare remained by approximately 12% lower than the means on record in the other states of the European Union [1].
In nature, all plant tissues contain vegetable fats in certain amounts (0.01...70%), which would theoretically mean that there is a variety of vegetal sources from which oils for human consumption can be extracted. Practically speaking, things are very different because in industry oils are extracted only from the parts of the plant that contain vegetal fats in economically acceptable quantities (at least 15...20% of the vegetable fats, commonly found in seeds, fruits, kernels or germs) [1].
As regards the extraction methods used, although many experiments are done to develop the procedures for the extraction of vegetable oils using supercritical fluids, and also by the GAME (Gas Assisted Mechanical Expression) method, currently, worldwide, we can talk about the existence of two dedicated extraction processes: mechanical pressing or mechanical expression (using hydraulic or screw presses) and solvent extraction, processes which may be applied independently or in succession, depending on the type of the raw oil,

the oil content thereof and the degree of extraction required to be attained. For example, in Romania, to extract vegetable oils from oleiferous seeds, in most cases the combined process is used: pressing the seed material, ensuring oil separation of up 80…85% , is followed by the solvent based extraction, a method by which the oil is separated from the remainder (up to 99…99.5%) [1].

2. MATERIALS AND METHODS

Mechanical expression is the oldest method used for oil extraction from seeds [6], [10], [11], [12]. The seeds are placed between permeable barriers and mechanical pressure is increased by reducing the volume available for the seeds. This way oil is squeezed from the seeds. In practice, this operation can take two shapes: a hydraulic, uni-axial press or a screw press (also called extruder or expeller). The advantages of a screw press (Figure 1) compared to a hydraulic press (Figure 2) are its slightly higher yield and its continuous mode of operation. Mechanical expression results in high quality oil, but has a relatively low yield. Generally it is only used for smaller capacity plants, speciality products or as a prepress operation in a large scale solvent extraction plant [16].

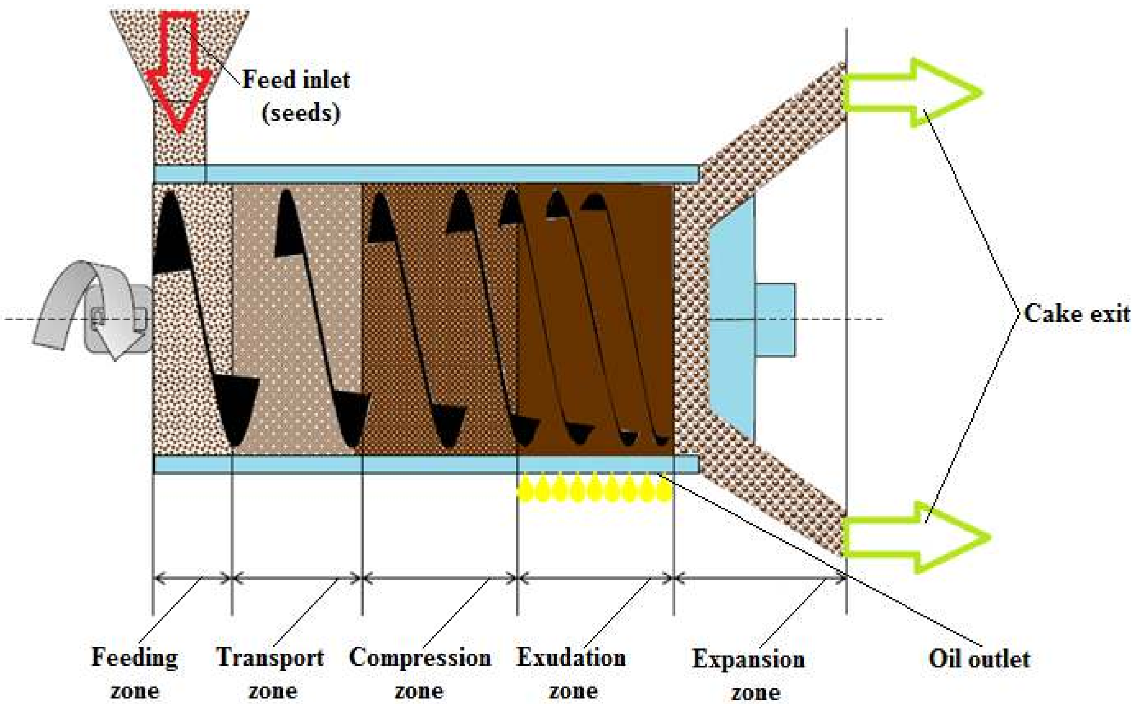

Figure 1: Schematic representation of the pressing process (screw presses) [15]

In a (continuous) solvent extraction process, the seeds are contacted with a solvent, generally hexane. The oil contained in the seeds is dissolved in the solvent after which solvent and solids are separated. The solvent/oil mixture (usually 20...33 wt% oil) is sent to the solvent recovery operation, where solvent is removed by evaporation [3], [9], [16]. The residual cake is sent to a desolventiser/toaster, which also removes the solvent by evaporation. Both oil and solids therefore undergo a heat treatment, which is detrimental for the oil and cake quality. The co-extraction of undesired components further reduces the quality of the oil. However, with this method it is possible to recover almost all of the oil from the seeds. Generally, this method is used in the high(est) capacity plants [10], [11], [16]. To further improve the efficiency of the process, the extraction can be preceded by a pre-pressing step. Here part of the oil is recovered by a screw press, which reduces the size of the extractor and improves the permeability of the solids for the solvent [2], [5], [16].
When the pressure and temperature of a compound are increased beyond the socalled critical values, the interface between the liquid and vapour phase disappears. This is the supercritical state, in which properties like density and viscosity can be varied continuously between those of the liquid and the vapour state by adjusting temperature and pressure [15], [16]. This also allows for a large change in solubility of solutes with a relatively small change in pressure and/or temperature. This makes supercritical fluids interesting candidates as extraction solvents. CO_2 has been the most used solvent up to now, because of its relatively low critical pressure and temperature, availability, low toxicity and low cost [16].

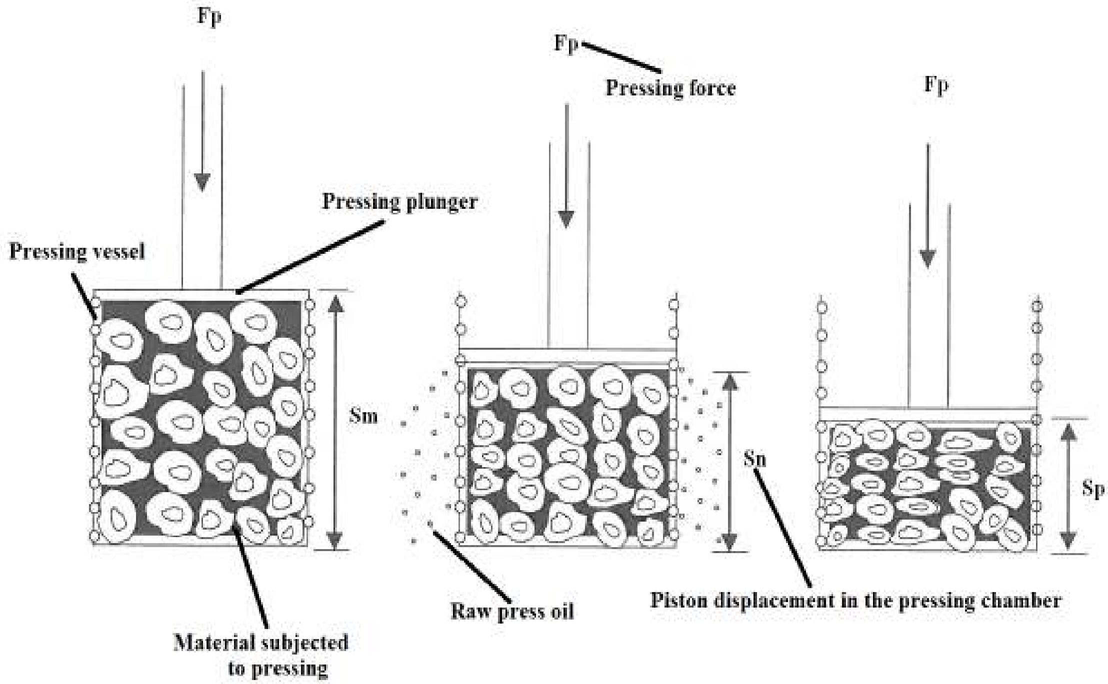

Figure 2: Schematic representation of the pressing process (hydraulic presses)

The operation of a screw press is similar, in theory, to a hydraulic press. The fixed part of the hydraulic press (press head) is here replaced by a plug of compressed material located at the discharge end of the press. This plug is stable under stationary operation of the press, that is to say it has a constant length. The mobile part of the hydraulic press (plunger) is portrayed by the screw which causes compression of matter.

3. RESULTS AND DISCUSSIONS

Within this paper, we limit ourselves to the state of the art concerning the continuous oil expression from oilseeds, the state of the art of hydraulic pressing of oilseeds being already described elsewhere. The effect of the process parameters and raw material on performance of mechanical continuous oil expression will be presented in the following.

Regardless of the oilseed raw material or the extraction process chosen, on an industrial scale, before the actual extraction of the oil, the size of oleiferous seeds and fruits is reduced by grinding them under the action of external forces. Because it determines achievement of high yields in oil and positively influence future operations (hydrothermal conditioning, extraction and refining), grinding is considered as an essential operation in the preparation of the oil materials used to obtain vegetable oil. The analysis of the grinding operation showed that the occurrence of this phenomenon relies on the following mechanical methods: shearing, crushing, friction and impact [1]. Although in most cases reducing the size of oleiferous seeds is done by the combination of different forms of the aforementioned methods mentioned, special attention is paid to the grinding process by crushing. Originally designed as a specific process to high consistency oilseeds, grinding by crushing has become increasingly used over time, due to the simplicity and satisfactory results obtained [1].

The stages of grinding by crushing, in the case of shelled oilseeds are presented graphically in Figure 3. The first stage (OA portion of the curve), starts when the upper crushing plate comes into contact with the upper dehusked seed, this stage is characterized by the elastic deformation of micro-asperities in the oily core. As can be seen, in the first stage, the slope is reduced. In stage II, (the portion AB of the curve), there is an elastic deformation of the core. Stage III, (BC portion of the curve) is characterized by the elastic-plastic deformation of the core. Seed cracking occurs at point C, which is characterized by the maximum resistance of the oleaginous seeds. Stage IV, (CD portion of the curve) characterizes seed grinding into smaller particles. In the first stage, the seed resistance decreases rapidly, which is corroborated with widening the existing cracks and occurrence of new ones. The local maximum curve appeared from cracking the newly obtained particles [1].

Temperature is parameter acting in several ways on the pressing performance. The rise in temperature causes a decrease in oil viscosity favorable to its flowing, but it can also alter the cellular structure and plasticity of the raw material (cooking). However, the problematic point when considering the effect of temperature on the pressing is to know which temperature is discussed (the temperature of feeding seed or the barrel temperature).

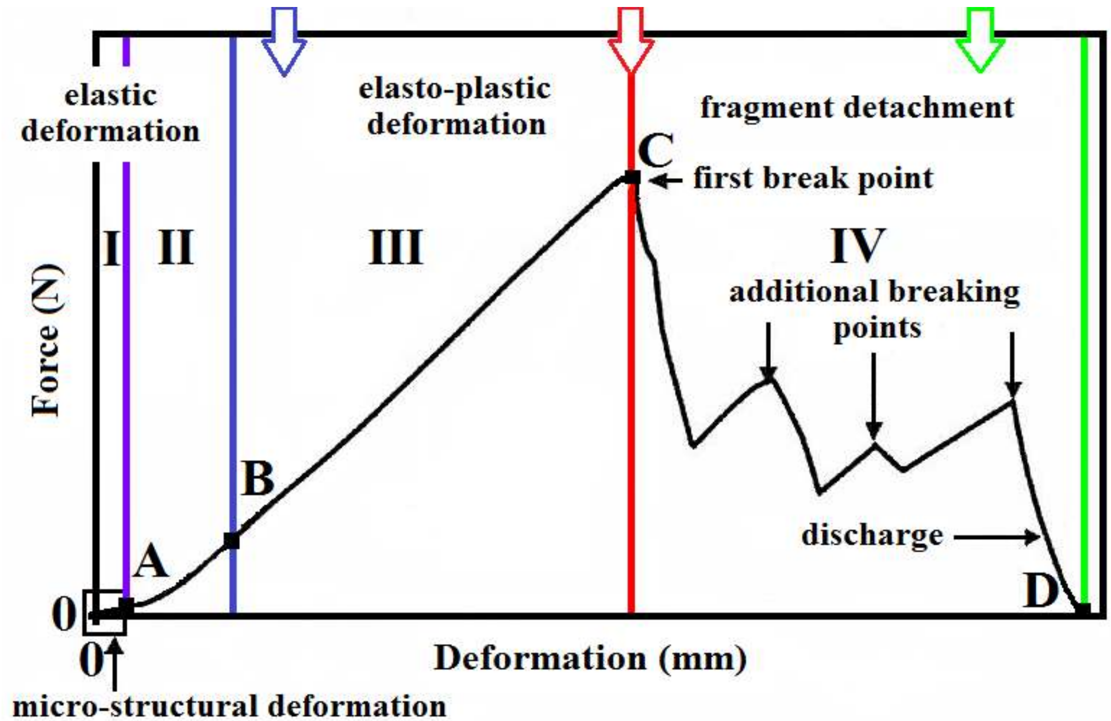

Figure 3: Stages of grinding by crushing in the case of shelled oilseeds

In general, whatever the seeds treated, the more pressure is applied, the higher is the oil extraction yield. Regarding the press capacity, the behavior is less predictable and depends on both the raw material processed (seed type) and the press model. The oil flow rate evolves with pressure similarly as capacity [15].

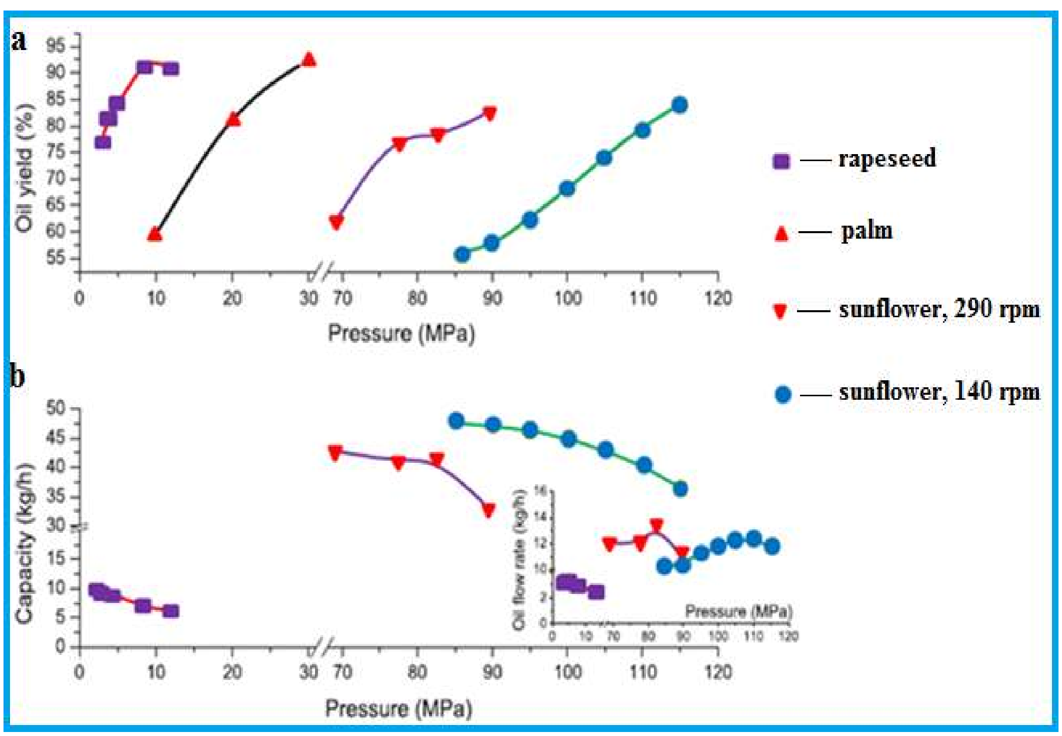

Figure 4: Effect of pressure on pressing performances: a-on oil yield; b-on press capacity

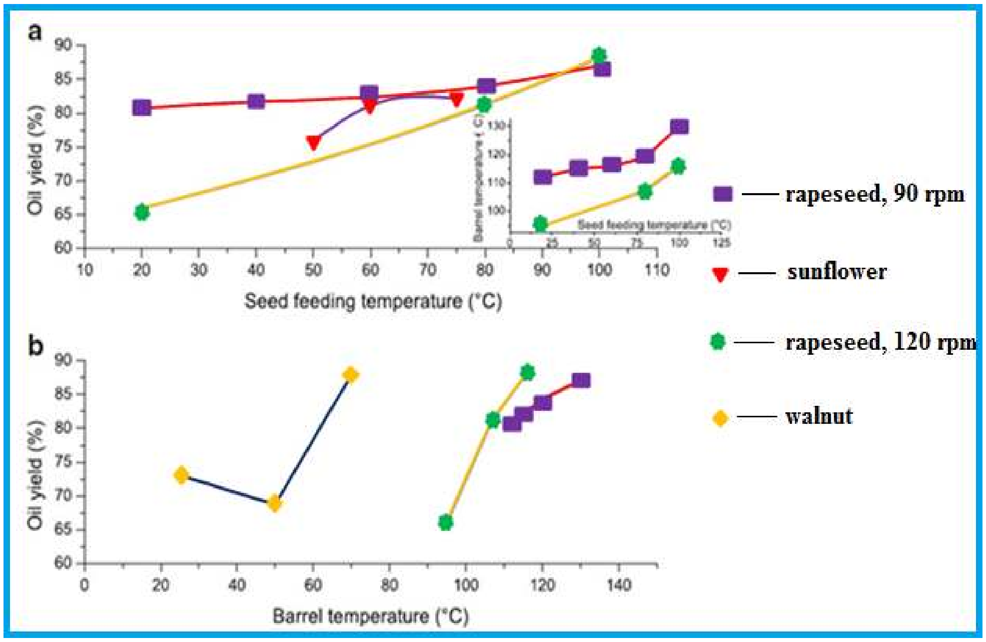

Figure 5: Effect of seed feeding temperature on oil yield-a; Effect of barrel temperature on oil yield-b

Screw rotation speed is an operating parameter that does not act directly on the performance of pressing. This parameter acts via a change in pressure and temperature in the barrel. Increasing the screw rotation speed causes a pressure decrease and a temperature increase. The balance between these two opposite phenomena leads to different yield modifications [15].

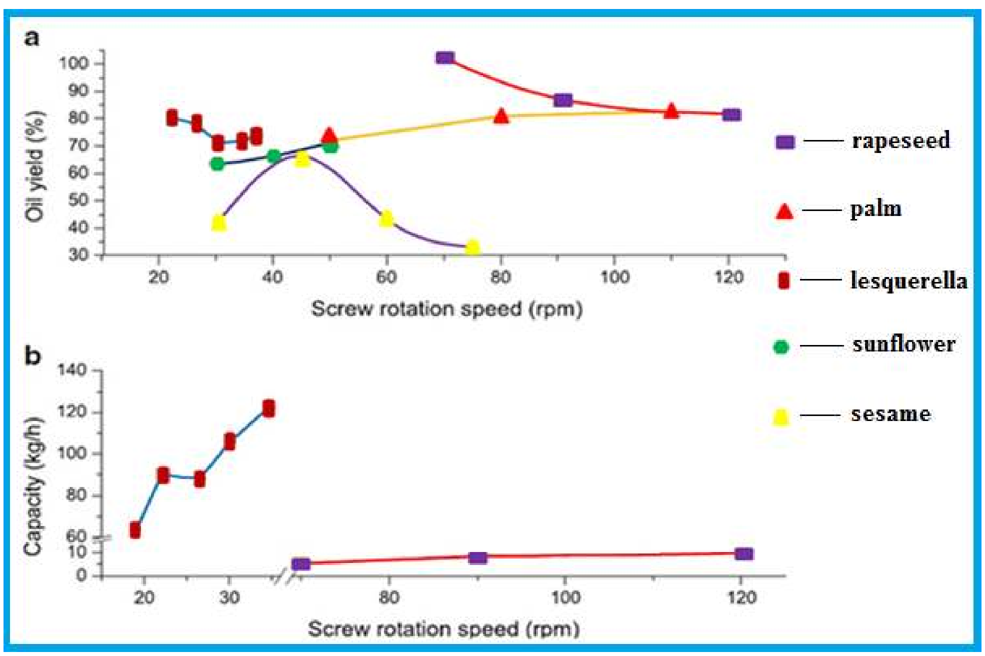

Figure 6: Effect of screw rotation speed on: a-oil yield; b-press capacity

4. CONCLUSIONS

Mechanical expression is the oldest method used for oil extraction from seeds. The seeds are placed between permeable barriers and mechanical pressure is increased by reducing the volume available for the seeds. This way oil is squeezed from the seeds. In practice, this operation can take two shapes: a hydraulic, uni-axial press or a screw press (also called extruder or expeller).

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Temperature is parameter acting in several ways on the pressing performance. The rise in temperature causes a decrease in oil viscosity favorable to its flowing, but it can also alter the cellular structure and plasticity of the raw material (cooking). In general, whatever the seeds treated, the more pressure is applied, the higher is the oil extraction yield.

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