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THE INFLUENCE OF PROCESS PARAMETERS ON MECHANICAL EXPRESSION OF SUNFLOWER OILSEEDS

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Abstract: *Separation of oil from oilseeds is an important processing operation. The process employed has a direct effect on the quality and quantity of protein and oil obtained from the oilseeds. Basically, two methods are used for this purpose. One is the solvent extraction method in which a solvent, when brought in contact with the preconditioned oilseed, dissolves the oil present in the seed and the separated mixture is later heated to evaporate the solvent and obtain the oil. The other method used involves mechanical oil expression. In this process, the preconditioned oilseed is passed through a screw press where a combination of high temperature and shear is used to crush the oilseed to release the oil. The objective of this study was to investigate several process parameters (pressure, time, temperature and moisture content) and their influence on mechanical expression of sunflower oilseeds.*
Keywords: *sunflower oilseeds, mechanical expression, process parameters, oil yield, oil quality*

1. INTRODUCTION

Worldwide, especially in industrialized countries, there is increasing trend in human consumption of vegetable oils, which can be explained by the advantages they pose in terms of food, compared with animal fats:

- are more easily assimilated (predominantly unsaturated fatty acids as to the saturated ones);
- are nutritionally superior due to the presence of polyunsaturated fatty acids;
- contain less cholesterol for the human body;
- are more suitable for food products (mayonnaise, sauces, dressings etc.).

Obtaining quality vegetable oils greatly depends on the physical, chemical and biological characteristics of the raw materials, as well as on the extraction procedure. Although numerous experiments are being conducted with the aim of developing the vegetable oils extraction method based on the use of supercritical fluids, at industrial level, in Romania, the separation of vegetable oils from oleaginous raw materials is being achieved by two procedures: mechanical expression and solvent extraction, which can be applied independently or successively, depending on the oil content of the oleaginous raw material and the desired extraction degree [1].
The issue of vegetable oils extraction from oleaginous raw materials is quite topical nowadays, being a major concern both for specialists, who are permanently working on finding solutions intended to improve this process (increasing extraction efficiency, reducing energy consumption, introducing various environmentally friendly technologies), but in the present situation, when the humanity is faced with a serious economic crisis, potential consumers seem to grow more and more concerned about this issue [1].

2. MATERIALS AND METHODS

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].
Considering the exceptional dietary qualities and the numerous industrial uses [3], [9], [12] of sunflower oil, and on top of that the prospect of using it on a large scale, together with the rapeseed oil, as a biofuel – biodiesel to be more precise [12], the materials which constitute the subject matter of this paper are the oleaginous sunflower seeds.
Sunflower seeds are achenes of variable dimensions (5...26 mm in length, 3...10 mm in width and 2...6 mm in thickness), generally in an elongated shape, pointed at the end attaching to the head. The chemical composition of the achenes is set forth in table 1, and they consist of a pericarp (hull), with a weight of 14...28% of the total weight of the seed (Table 2), of a ligneous consistency, ashy, white, black-coloured or striped, and the oleaginous kernel, which can store up to 60...65% oil content [2].
As may be seen from the data contained in table 1, besides the high oil content, oleaginous seeds also contain significant quantities of protein substances, which is why sunflower is classified as a high-protein oil content plant.

Table 1: Chemical composition of sunflower oleaginous seeds [2], [3], [5], [9], [12]

Designation	Value
Humidity, %	9...11
Raw oil, %	44...48
Gross proteins , %	18...20
Non-nitrogenous extractive substances, %	10...15
Cellulose, %	14...18
Ash, %	2...3

Table 2: Main characteristics of sunflower oleaginous seeds [2], [9]

Designation	Value
Hectolitre weight, kg/hl	38...42
Hull content, %	14...28
Equivalent diameter, mm	5.64
Density, kg/m^3	730
Bulk density, kg/m^3	438
Porosity index, %	40

3. RESULTS AND DISCUSSIONS

To separate the vegetable oil from the sunflower seeds, the combined process is almost always used in industry practice, namely the pressing of the oleaginous material, which enables an oil separation of up to 80...85%, followed by solvent extraction, whereby the remaining oil is being separated (99…99.5%) [3], [9].
The combined procedure (expression-solvent extraction) is applied in the processing of oleaginous raw materials with a minimum oil content of 30%. Raw materials with lower oil content are directly processed by solvent extraction, as the low yield of their expression does not justify the costs generated by this method [9].
Depending on the characteristics of oleaginous seeds, the degree of equipment of the processing facilities and the desired extraction degree, there are 5 main categories of oleaginous material which can be subjected to extraction by pressing: oleaginous seeds as such (having reached technological maturity, shelled and dried but unshelled, ground or hydrothermally processed), ground unshelled oleaginous seeds, ground unshelled but hydrothermally processed oleaginous seeds, ground shelled oleaginous seeds, ground shelled and hydrothermally processed oleaginous seeds [1].
Considering the above, we may note that the grinding of oleaginous seeds is an omnipresent operation in the vegetable oil processing technologies (except for the first situation, very rarely met in current industrial practice on account of the low quality of the obtained oil). As regards the hulling of the oleaginous seeds and the hydrothermal processing of the ground seeds, although these perceived as optional operations, both the quality of oil and that of the resulting seed meal, as well as the enhancement of extraction yields, greatly depend on their application [4], [5], [12].

Due to their chemical composition characterized by a low botanical oil content (0.5...6%) and a high cellulose content (up to 60% in the case of sunflower seeds), the hulls of oleaginous seeds are an inert material in processing and unwanted in the composition of the seed meal. Therefore, as far as this is possible, hulls are partially eliminated by oleaginous seed shelling or hulling (a certain percentage of hulls – approximately 8...10% in the case of sunflower seeds – is not removed from the hulled material because it ensures optimal conditions for grinding and pressing). Considering that the hulling of oleaginous seeds involves two steps: cracking and separating the hull from the kernel, and separating the hulls from the resulting mixture, respectively, in order to obtain satisfactory results both from a technological and an economical point of view, only those oleaginous seeds with a high content of hull, which is loosely attached to the kernel (sunflower, soya, castor oil seeds, cotton seeds, etc.) shall be put through a hulling process.

In the case of sunflower seeds, the main advantages derived from the hulling thereof lie in the:

- improvement in the quality of seed meal, by reducing the cellulose content and increasing the protein content: the seed meal obtained from unhulled sunflower seeds contains approximately 25% protein substances and 25...28% cellulose, that obtained from partially hulled seeds (10...12% hull remaining in the hulled material) contains 35...37% protein substances and 18% cellulose, while the seed meal obtained from mostly hulled seeds (6...8.5% hull remaining in the hulled material) contains 40...42% protein substances and 12...14% cellulose [3];
- increase in the processing capacity of the grinding rolls, of the hydrothermal processing facilities, of the pressing equipment, as well as of the extractors;
- reduction of equipment wear, especially on the grinding rolls and presses, given that the sunflower seed hull contains silicon dioxide, which is an abrasive material;
- reduction of oil losses occurring during the expression and solvent extraction processes;
- reduction of the wax content in the raw press oil (waxes, due to their high melting point, give to the oil a specific cloudiness – white sediments on the bottom of containers – for which reason these are being removed during the refining process through winterization);
- salvage of hulls and their use as fuel, in the manufacture of various products (furfural) or as an ingredient in forage for ruminants (ground hulls easily absorb molasses) etc.

The hydrothermal conditioning of the ground oleaginous seeds is an integral part of the material preparation operations preceding oil extraction by pressing and sometimes even solvent oil extraction, and it involves the performance of the following 2 operations:

- moistening the ground seeds up to an optimal humidity, specific to each oleaginous raw material;
- heating and drying the ground seeds until obtaining a specific cellular structure, enabling an easier oil separation during the process of extraction by pressing.

During the first stage, simultaneously with the feeding of the moistening agent (water spraying or steam injection in the hydrothermal processing system) the ground oleaginous seeds are heated (in order to stop the enzymatic activity, favoured by the presence of water and who could cause and increase in oil acidity), operation which is continued in the second stage, during which the feeding of moistening agent is stopped.

Two phase result from the moistening of the ground oleaginous seeds: a solid phase (gel), consisting mostly of protein substances, with a marked absorbent character and a liquid phase, consisting of oil and water. Both components of the liquid phase are moistening the solid phase yet, given the fact that the superficial tension of water is higher than that of oil, it exerts a better moistening action, for which reason water intervenes between the solid phase and oil, thus reducing the forces retaining oil at the surface and in the open capillaries of the ground seed particles. At the same time, when soaked in water, the solid phase (proteins) increase their volume thereby causing a reduction in the diameters of capillaries and micro-capillaries of the ground seeds and thus forcing oil to surface. During the second stage, the heating of the ground seeds determines a drop in the superficial tension of oil but also a reduction in its viscosity, which makes it easier for the oil to be released from the closed capillaries of the ground seeds during the pressing process [12].

Although the hydrothermal processing of the ground oleaginous seeds is an extremely complex operation, which needs to be carried out under controlled conditions, through its application, due to the physical, chemical and structural transformations occurring in the oleaginous material, it becomes fit for extraction by pressing (forming an optimal cellular structure permitting to achieve maximum yields of oil on pressing).

After the grinding of the hulled oleaginous seeds and the hydrothermal processing of the resulting ground seeds, the technological process of vegetable oil extraction from sunflower seeds continues with the pressing of the hydrothermally processed oleaginous material. For that purpose, the oleaginous material heated at temperatures comprised between 60 and 95 Celsius degrees (in the case of sunflower seeds) can be transferred from the hydrothermal processing system directly inside the feeding vat of the pressing equipment. The results of the experimental researches have pointed out that in this temperature range (60...95 Celsius degrees), a maximum extraction degree can be attained (Figure 1, 2, 3) and at the same time the obtained oil is of the highest quality, for which reason the ground oleaginous seeds are transferred from the hydrothermal processing system directly to the pressing equipment without any intermediate processing [5], 12].

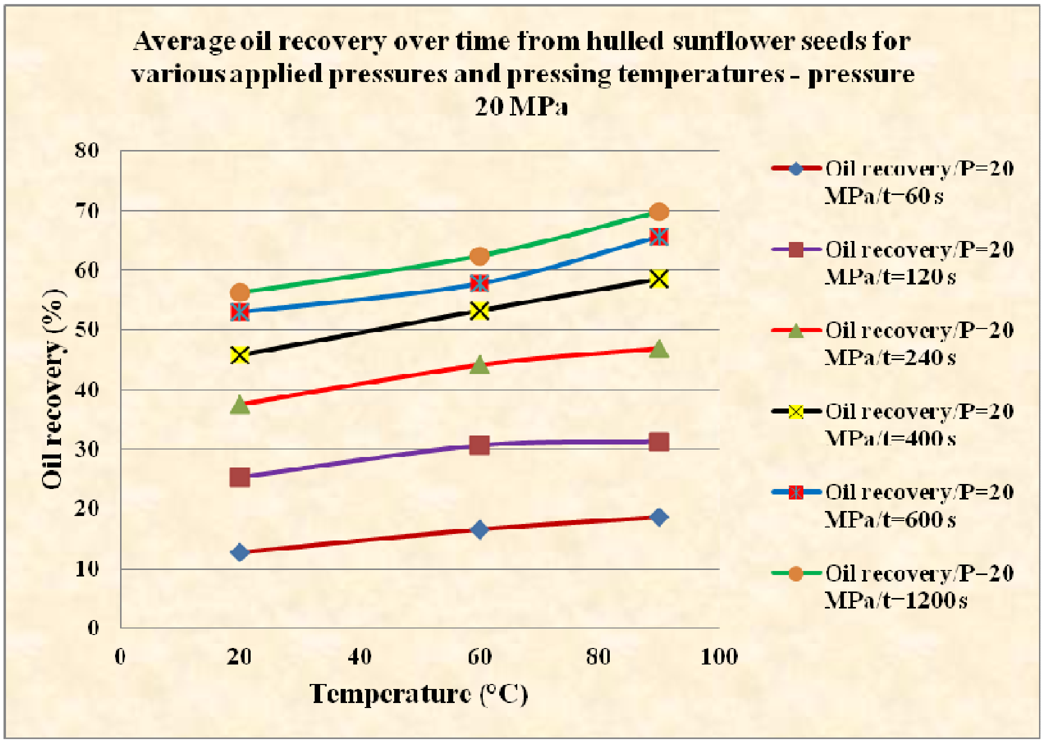

Figure 1: Average oil recovery over time from hulled sunflower seeds for various applied pressures and pressing temperatures – pressure: 20 MPa

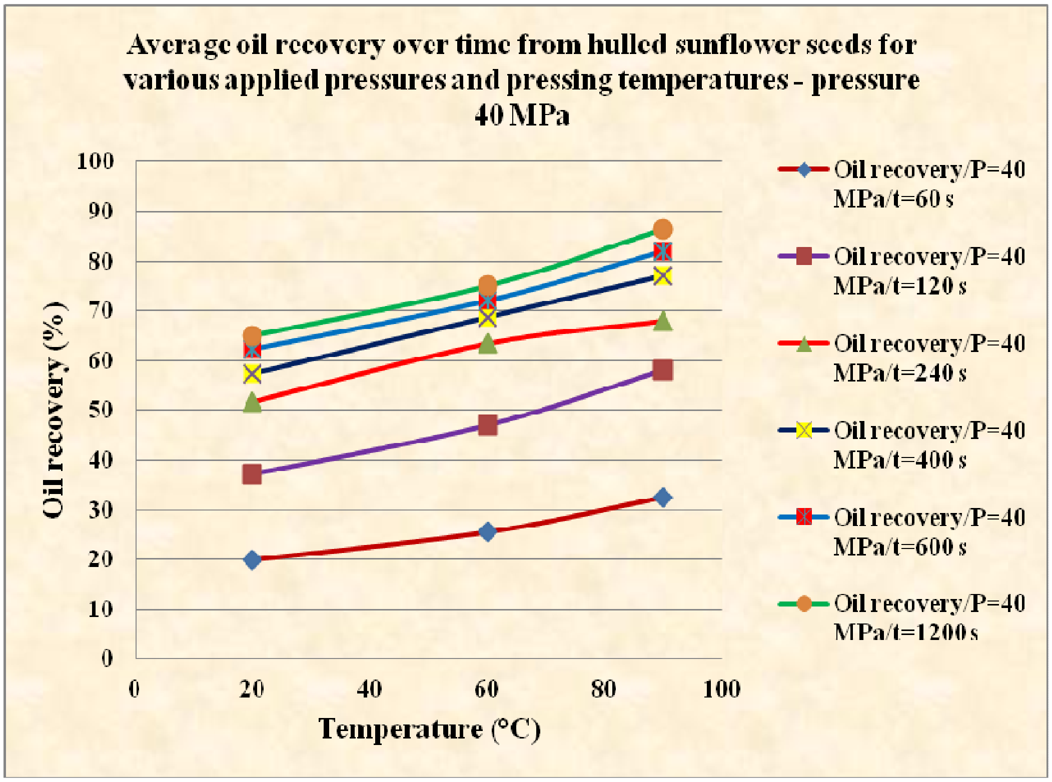

Figure 2: Average oil recovery over time from hulled sunflower seeds for various applied pressures and pressing temperatures – pressure: 40 MPa

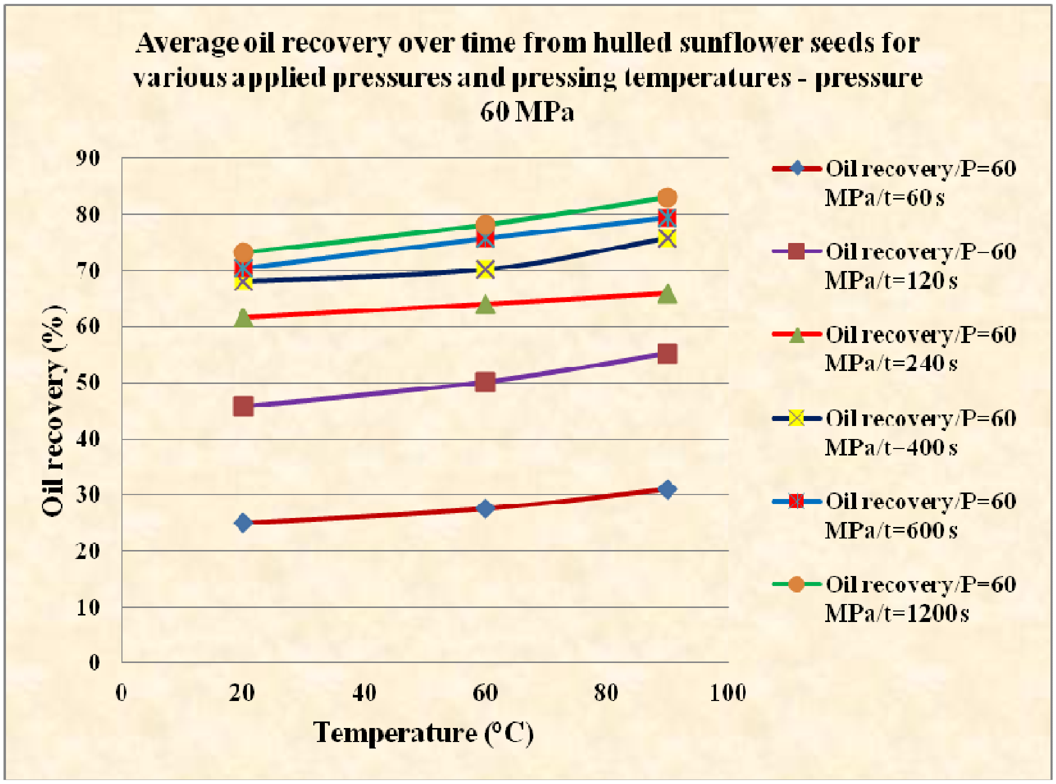

Figure 3: Average oil recovery over time from hulled sunflower seeds for various applied pressures and pressing temperatures – pressure: 60 MPa

Following the introduction of the oleaginous material into the pressing chamber (Figure 4), the first thing that occurs is the separation of oil (over a short period of time) without any exterior action, only through the effect of the gravitational field and of the pressure of material layers. This first phase unfolds as a sheer filtering process under the influence of a hydrostatic pressure. The actual pressing process is achieved through the action of an active organ (piston in our case), which initially achieves a compression of the oleaginous materials aimed at eliminating air pockets by evacuating the air existing between the particles of ground seeds. This is followed by the separation of the oil kept on the surface of the particles due to the surface forces of the molecular field, through the channels formed between the particles [4], [5], [8], [11].

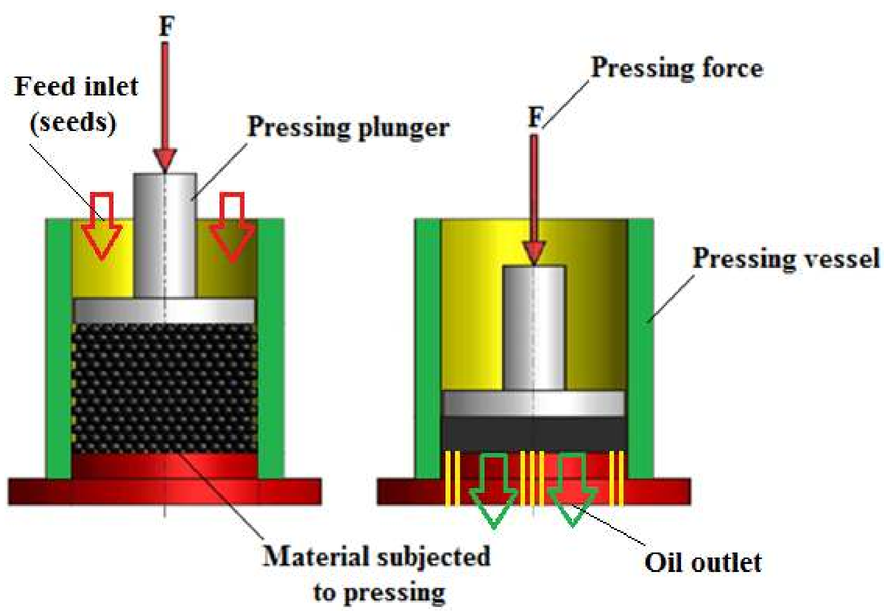

Figure 4: Schematic representation of the pressing process (hydraulic presses) [10]

The increase in the pressing forces engenders a decrease in particle volume, which causes the oil to be eliminated from the particle capillaries, at the same time as the separation of the oil existing on the surface thereof. The increase in the pressure exerted on the ground oleaginous seeds needs to be gradual, so that the finely ground particles do not obstruct the capillaries thereby blocking oil evacuation [11].

When the space between the surfaces of two particles becomes so narrow that the oil film is subjected to the retention forces exerted by both particle surfaces, the oil cannot be eliminated anymore, the film breaks in several places, the surfaces hit one against the other and the so-called oilseed cakes are formed.

4. CONCLUSIONS

Sunflower oil is an excellent edible oil which has come to be more and more appreciated in modern dietetics due to its high unsaturated fatty acids content (85...91%) mostly represented by the oleic and linoleic acid (up to 65%), one of the essential nutritive fatty acids. Unlike the other vegetable oils, sunflower oil ideally combines the high nutritive value with stability and a long shelf-life, owing to the absence of the linolenic acid. From this perspective, no other vegetable oil can stand comparison.

The results of the experimental researches have pointed out that in this temperature range (60...95 Celsius degrees), a maximum extraction degree can be attained and at the same time the obtained oil is of the highest quality.

Considering the structure of the ground and thermally processed oleaginous material and the manner in which oil extraction is achieved, the pressing may be defined as the physical process of partial separation, under the action exerted by outer forces, of the liquid phase (oil) from an heterogeneous solid-liquid mixture (ground oleaginous seeds). The essential requirement to be met by the materials to be put through the pressing process is that the skeleton of the solid substance of the phases system be compressible and that draining capillaries be formed, enabling the passing of the liquid phase.

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