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CURRENT TECHNIQUES AND PROCESSES FOR VEGETABLE OIL EXTRACTION FROM OILSEED CROPS

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Abstract: *The vegetable oil industry is a fundamental branch of the world economy, producing edible oils, technical oils and various other derived products. In this industry, the raw material is represented by oilseed crops of which vegetable oils are extracted through well-established processes. The main extraction methods applied at industrial level, highlighting the basic characteristics, their advantages and drawbacks, are the main subject of this work.*

Key words: *oil industry, yield, mechanical pressing, solvent extraction, supercritical fluids.*

1. Introduction

In the vegetable world, there are many species of plants that can gather in their component parts (in seeds, fruits, kernels, tubers, germs etc.), significant quantities of lipids, usually between 35 and 70%, such plants being known as oleaginous plants or oil plants [3].

The number of oil plants is very high. Therefore, from nearly 100 species of known oleaginous plants, around 40 species, grouped in 16 important botanic families are currently highlighted at international level, and these are: family Compositae or Asteraceae (sunflower, safflower), family Cruciferae or Brassicaceae (colza, camelina), family Fabaceae (soybean, groundnut), family Euphorbiaceae (castor oil plant, tung oil tree), family Malvaceae (cotton), family Papaveraceae (poppy), family Rosaceae (almond), family Pedaliaceae (sesame), family Juglandaceae (walnut), family Arecaceae (oil palm tree, coconut tree), family Oleaceae (olive tree), family Linaceae (linseed), family Cucurbitaceae (pumpkin), family Cannabaceae (hemp), family Solanaceae (tobacco, tomatoes) and family Vitaceae (grapevine).

The main purpose of oleaginous plants cultivation is the extraction of fats and edible and industrial oils, following both high extraction yields and also obtaining high quality end products.

The first methods used to obtain vegetable oils from various types of oil raw materials referred to hot water extraction. The technique is also used nowadays in certain parts of the world, in areas that are less developed from the industrial point of view, but which are

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characterized by a high number of oil raw materials. Since this method was allowing low oil yields, people have tried to improve the extraction process, determining the entry of primitive presses. Oilseeds and fruits which were previously ground by two tough cases (usually stones), were introduced in the crevice of a tree trunk and weights were put over for pressing. In order to collect the extracted oil, the tree trunk has a crack in the lower part [5].

The evolution in this field has continued so in the Ancient Greece (the archaic period of Greece 750...490 BC) and then in the Ancient Rome much improved procedures were used for olive oil extraction. A discovery that shook up the technical world goes back in the same period of time (3rd century BC), Archimedes' screw, with various industrial applications, also in the field of vegetable oil extraction by mechanical pressing.

Quite a long period of time with no important achievements regarding vegetable oil extraction follows, more exactly up to 1795, when Joseph Bramah registered a patent that remained known in history as Bramah's press or the first hydraulic press.

Considering the discontinuous working hours of the hydraulic presses, researches have continued and so, in the beginning of the 20th century, in the USA, V.D. Anderson has developed and improved subsequently the screw press oil.

Regarding the current extraction methods, even though many experiments are done in order to develop extraction procedures for vegetable oils by supercritical fluids (especially supercritical CO_2), at international level we can mention the existence of two established extraction procedures: extraction by mechanical pressing (in the screw presses or in the hydraulic presses) and solvent extraction. Such procedures may be applied independently or successively, depending on the type of oil raw material, its oil content and the desired extraction degree. For instance, the combined procedure is being used in Romania, for the extraction of the vegetable oils from oilseeds: oil material pressing by which a separation of oil of up to 80…85% may be done, is followed by the solvent extraction, a method by which it is being separated by the rest of the oil (up to 99…99.5%).

2. Extraction of Vegetable Oils by Mechanical Pressing

Mechanical pressing or expression is one of the oldest extraction methods for vegetable oils from oil raw materials. Mechanical pressing can be defined as the physical process of partial separation, under the action of external forces, of the liquid phase (the oil), from a solid-liquid heterogeneous mixture (oil grinding). The extent to which the separation of the liquid phase is done mainly depends on the constructive type of the pressing equipment and on the properties of the raw material submitted to extraction by mechanical pressing. Following oil material pressing it results crude oil press and broken (for screw presses) or crude oil press and cake (for hydraulic presses).

Mechanical pressing is a very complicated operation, mainly involving aggregated and semi aggregated solid mechanics phenomena, but also from the mechanics of liquids separating from solids. Because of the complexity of the phenomena that appear during pressing, there is no uniform theory of the process yet, the concepts known up to now being just semi-theoretical concepts, tending to generalize the aspects noticed in laboratory or during industrial equipment running.

Oil material pressing normally follows its hydrothermal treatment operation. At industrial level, the oil raw material is sent from the hydrothermal treatment equipment to the interior of the feeding tank of the pressing equipment. Following the intake of the oil material in the pressing chamber, there is a separation of a small quantity of oil with no action from the exterior, only by the effect of the gravitational field and of the pressure of material layers. This first phase will take be a pure filtering process under the influence of a hydrostatic pressure. The real pressing process happens under the action of an active organ (piston or screw), that is doing in the beginning a compression of the oil material in view of eliminating the blanks between the grinding particles. The increase of the pressing forces then determines a reduction of the particles' volume, resulting into oil disposal from their capillaries, at the same time with the separation of the oil at the particles' surface. We must state that the increase of the pressure exercised on the oil grinding must be gradual for the fine grinding particles not to obstruct the capillaries and block oil discharge [3].

The extraction process by pressing in hydraulic presses is highlighted in Figure 1 and the extraction process by pressing in screw presses is presented in Figure 2.

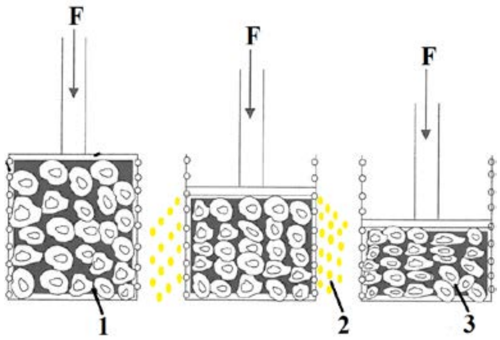

Fig. 1. *Schematic representation of the pressing process (hydraulic presses): F – pressing force, 1 – raw material, 2 – crude oil press, 3 – press cake*

When the distance between the surfaces of two particles becomes so small that the oil film is submitted to retention forces exercised by both surfaces of the particles, the oil cannot be discharged anymore, the oil film breaks in several places, and the surfaces of the particles get in contact with each other and the so-called briquetting starts, that is formation of the broken (press cakes).

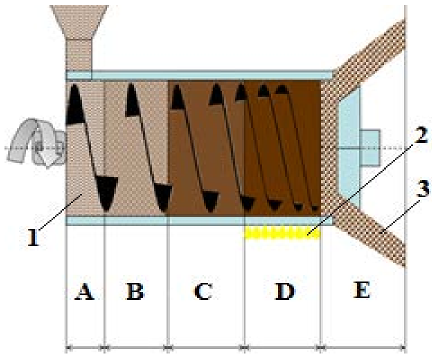

Fig. 2. *Schematic representation of the pressing process (screw presses): A – feeding zone, B – transport zone, C – compression zone, D – exudation zone, E – expansion zone, 1 – raw material, 2 – crude oil press, 3 – broken*

Quality assessment of the extraction process by pressing can be done taking into account the oil yield, by this relation:

$$W = CW_0 \frac{\sqrt{P\sqrt[6]{\theta}}}{\sqrt{\vartheta^z}} \qquad (1)$$

where:

W is the oil yield;

C – a constant for one kind of oilseed;

W_0 – the oil content of the seed;

P – the pressure applied;

θ – the pressing time;

υ – the kinematic viscosity of the oil at press temperature;

z – the exponent on viscosity factor varying from 1/6 to 1/2.

Press efficiency can be calculated from the relation: W/W_0 [9].

The big advantage of the extraction by mechanical pressing is that no chemicals are being used during this process, obtaining a high quality product that can be consumed immediately after extraction. Other advantages relate to the low purchase prices of the equipment, as well as to the energy consumption during pressing – low energy consumptions as compared to solvent oil extraction or supercritical fluids [6].

The main downside of the extraction by mechanical pressing refers to the lower oil yield, the separated oil quantity rarely exceeding 85%. According to [4], because of the lower yield of this method, a quantity of edible oil amounting to 57 million dollars will be lost every year.

3. Solvent Extraction

Regarding the solvent extraction, the process is often used at industrial level, having the benefit of a high extraction degree. A separation of oil of up to 99...99.5% can be done, being, from this point of view, the most efficient method known and developed up to now [6].

Solvent oil extraction is a typical mass transfer operation, by oil solubilisation in a dissolvent, where the other components of the oil grinding are insoluble. The predominant role in extraction is played by the diffusion that may be: molecular, by convection, by cellular membranes etc.

Direct solvent extraction generally applies to oil raw material with low oil content, while the combined process mechanical pressing-solvent extraction applies to oil raw material with a minimum content of 30...35% oil [5].

The method has the drawback of using more expensive chemical solvents and equipment, as compared to pressing tools, for instance. Another problem is the removal of the solvent from oil that must be done so that consumer’s health is not endangered, and the environment is not polluted. Moreover, secondary products can be used for animal fodder purposes only if the solvent removal was done fully.

The choice of a solvent is done by taking into consideration several factors, such as: its extraction capacity, the effects of the solvent on oil properties, the influence of the solvent on process safety, solvent volatility and stability, the economic reasoning. Moreover, the solvent must be non-polar, hydrophobic and must have a dielectric constant close to oils’.

The extraction capacity of a solvent mainly depends on the following factors: the type of oil raw material and, at the same time, of the oil, the type of solvent, temperature, length of the contact between the solvent and the oil raw material, the conditions of pressing and the other phases of the technological process.

Currently, the solvent used the most at industrial level is hexane, due to the vaporization easiness, as well as due to the fact that this solvent does not leave any unpleasant smell or taste in the extracted oil. Nevertheless, in 1990, in the USA, in a law regarding environment protection (The Clean Air Act), it is considered that hexane is one of the 189 hazardous atmospheric pollutants, and researchers were encouraged to look for alternative solutions in view of extracting vegetable oils with solvents.

4. Extraction of Vegetable Oils by Supercritical Fluids

Although the solvent extraction is efficient from the economic point of view, with high oil outputs, researchers have constantly searched for new alternatives for vegetable oil extraction. One of the extraction techniques that became more and more popular lately is the extraction by supercritical fluids. Among the extraction methods by supercritical fluids, the most developed and often used is the extraction by CO_2. Basically, the extraction by supercritical fluids is a version of the solid-liquid extraction, where the extraction solvent is replaced by a supercritical fluid [5].

Although the critical point of substances was discovered by Cagniard de la Tour in 1820, and supercritical fluid utility as solvents has been proved ever since 1870, the application of this extraction method in vegetable oil industry is relatively recent. In this sense, there is information sending back to year 1980, when the method was applied for soybeans, cottonseed, canola seeds and sunflower seeds oils extraction. This is when it was noticed that oils that were obtained by such a method were adequate from the quality point of view, lighter in colour than solvent extracted oils, and refining was done easier. Moreover, protein quality was similar to that of the proteins resulted following solvent extraction.

Despite these advantages, the method was disregarded, failing to impose at industrial level before the already enshrined solvent extraction method. Supercritical extraction with CO_2 is a simpler method, easier to apply than the hexane extraction (regarding solvent vaporization there are clear advantages). At its turn, CO_2 extraction has some drawbacks: high costs of the equipment necessary to make the extraction and the inability to continuously process high volumes of oil products.

These two elements were setbacks in the development and assertion of this method at industrial level. Nevertheless, researches in the field of equipment, but also Governmental regulations regarding hexane use are solid grounds that make us believe that this method shall impose in the near future at industrial level. Moreover, an extremely important role is played by consumers, who are more and more concerned about the quality of purchased products.

5. Conclusions

- The plants that can gather in their component parts significant quantities of lipids make up the category of oil plants.
- The main purpose of oil plants cultivation is the extraction of edible and technical oils, by characteristic processes, aiming both at reaching high extraction outputs and obtaining quality end products.
- For the extraction of vegetable oils from the oilseed crops there are two dedicated processes: extraction by pressing and solvent extraction, but also a process that becomes more and more popular at industrial level: extraction by supercritical fluids.
- Extraction by mechanical pressing may be defined as the physical process of partial separation, under the action of exterior forces, of the liquid phase, from a solid-liquid heterogeneous mixture.
- The advantages of extraction by mechanical pressing refer to obtaining a high quality oil, for the low purchase costs of the equipment, but also low energy consumption, while the main drawback of this method is the lower oil yield.
- Solvent oil extraction is a typical mass transfer operation, done by oil solubilisation in a dissolvent, where the other components of the oil grinding are insoluble.
- Solvent extraction has the advantage of a high extraction degree, being, from this point of view, the most efficient method known and developed up to present, while the main drawbacks refer to chemicals' use, to the lower quality of the oil, but also to the high cost of the processing equipment.
- Extraction of supercritical fluids is a version of solid-liquid extraction, where solvent extraction is replaced by a supercritical fluid, usually CO_2.

- The quality of the oil obtained by extraction with supercritical fluids is close to the quality of the oil obtained by mechanical pressing.
- The main drawbacks of the extraction by supercritical fluids refer to the high costs of the equipment and to the inability to make the continuous processing of high volumes of oil products.
- From the point of view of the consumer, following the study of the three processes, I consider that the best extraction method is oilseed crops mechanical pressing.

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