ACTUAL METHODS FOR OBTAINING VEGETABLE OIL FROM OILSEEDS

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ABSTRACT

Vegetable oils are an important component for both food (for feeding, margarine and canned food industry, bakery, confectionery) and for non-food industry (production of detergents, paints, special varnishes, fatty acids, pharmaceuticals and cosmetics products, and painting). Vegetable oils and fats are found in nature in plant tissue, being concentrated in seeds, pulp, stone fruits, and in the tubers or sprouts. In our country, the main raw material is represented by the oleaginous plants which produce seed. The oil can be obtained from different categories of plants: plants with oil concentrated in seeds (sunflower, soybean, rapeseed etc.), plants producing oleaginous fruits (olive, coconut and palm), plants producing oleaginous tubers (peanuts) and plants producing oleaginous germ (corn). Fatty materials processing is somehow different, varying with its nature and oil content. Thus, for centuries, various methods were adopted for oil extraction from oilseeds. The purpose of those extraction methods was to optimize the process by collecting the maximum quantity of the existing oil in oilseeds with the minimum costs.

1. INTRODUCTION

Oilseeds represent one of the most important components of modern agriculture. This is due to the fact that they provide easily highly nutritious human and animal food. Nutritionally, oils obtained from oilseeds provide the calories, vitamins and essential fatty acids in the human diet, while the de-oiled cake is a valuable source of protein for animal feeds,[4].

In plants, fatty matter is concentrated only in some parts such as seeds, fruits and tubers, stone fruits, sprouts, representing a reserve substance that the plant uses during its development as a source of energy. Although the oilseeds field is very wide, plants that can be used as raw material in vegetable oils industry are slightly because many of them have low oil content - being unprofitable, others with higher oil content present difficulties in oil extraction because of the special structure of the plant, [3].

Oleaginous products industry manufactures edible oils and oils non edible. Edible oils (which is about 2/3 of the total volume of the oil products) are used directly in food or used in the industry of margarine, mayonnaise, cooking fats, bakery products, confectionery, canned food, confectionery and others, and the non edible oils (representing one third of the total volume of oil produced) are used in production of detergents, paint, varnish, fatty acids, pharmaceuticals and cosmetics, [6]. The request for the vegetable oil industry increases with increasing population through the discovery of new uses. Thus, to satisfy the vegetable oil demand, it is necessary that the oil extraction methods to be faster and more efficient, [1]. The oil extraction methods from oleaginous materials are designed to obtain high quality oil with minimal undesirable components, achieve high extraction yields and produce high value meal, [10].

2. DESCRIPTION OF EXTRACTION METHODS

Fatty materials processing is somehow different, varying with its nature and oil content. Thus, for centuries, various methods were adopted for oil extraction from oilseeds. The purpose of those extraction methods was to optimize the process by collecting the maximum quantity of the existing oil in oilseeds with the minimum costs. Currently, worldwide there are four basic methods for obtaining vegetable oil: chemical extraction, supercritical fluid extraction, steam distillation and mechanical extraction.

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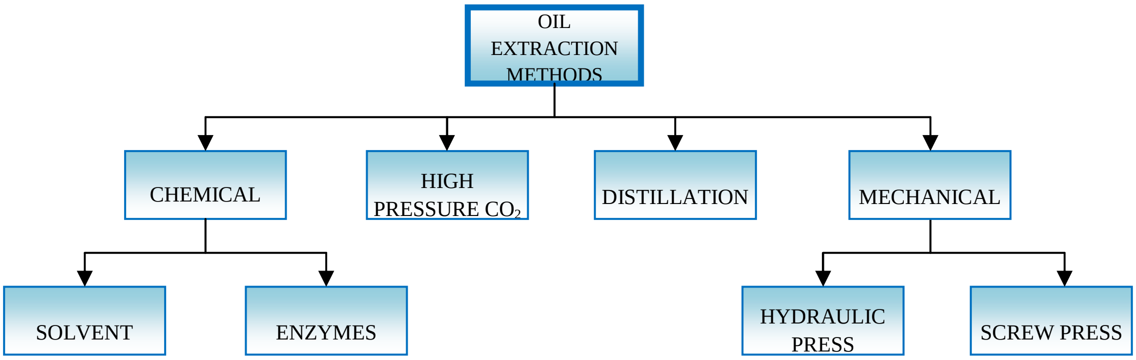


Figure 1: Basic methods for oil extraction, [12]

The most common method of extracting edible oil from oleaginous material, which has been practiced for thousands of years, is ***mechanical pressing*** of oilseeds. Mechanical oil extraction (also known as ***pressing***) is based on mechanical compression of oleaginous materials. Through pressing, oil is separated from the oleaginous material (solid-liquid mixture) under the action of compressive external forces that arise in special machines called presses. This method ensures extraction of a non-contaminated, protein-rich low fat cake at relatively low-cost. The disadvantage of this method is that the mechanical presses do not have high extraction efficiencies, about 8-14% of the available oil remain in the press cake, [2].

During the Roman and Byzantine periods, the number of oil presses was in the thousands; in the area of the Golan Heights alone, 109 oil presses were found in 58 ancient sites, most of them operated during this period. The olive oil production process was based on two major steps: first step requires crushing the olives using a crushing stone, and collecting them into a basket; second step is done on another installation: the basket is pressed with force, extracting the oil out of the crushed olives and collecting the juice into a storing vat, [8]. Currently, pressing operation may be conducted in hydraulic presses, which are driven by fluid pressure, or in screw presses, where the pressing force is created by a helical body (worm) which rotates in a closed space (press chamber). Hydraulic oil press, so named because it works on the principle of the hydraulic ram, are originary from England and was first patented in 1795 by Joseph Bramah,[4].

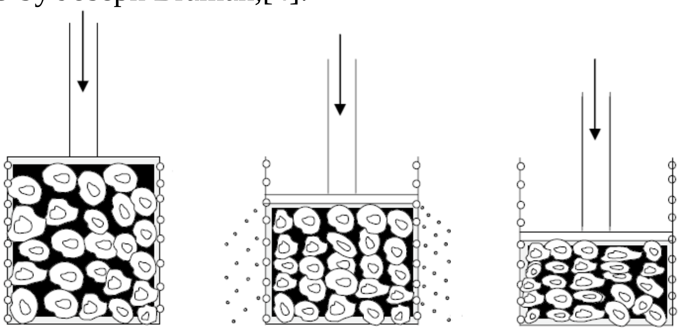
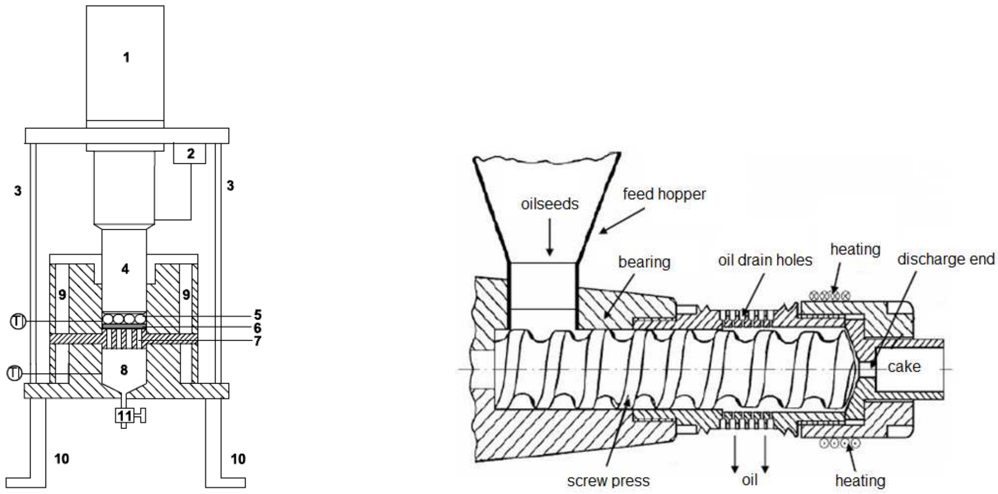


Figure 2: Stages of hydraulic expressions, [11]
a – initial stage; b – dynamic stage; c – consolidation stage (final stage).

Hydraulic expression of oil involves application of pressure through a ram to digested oleaginous material mash in a cylindrical cage. The cylindrical cage is usually perforated laterally. This results in axial compaction and radial oil flow. In a typical hydraulic pressing of vegetable oil seeds three distinct stages can be identified (fig. 2), [11]. The first cottonseed oil mill constructed in the United States (1920) utilized a hydraulic press. Seeds in filter bags were manually loaded into perforated, horizontal boxes between the head block and the ram of the press. Boxes were pressed together by applying hydraulic pressure on the ram. Oil was pressed out through the filter bag. Then the filter bag containing spent cake was manually removed from the hydraulic press. Later versions of the hydraulic presses used cages instead of filter bags, [10].

In figure 3(a) is schematic represented a hydraulic press. Seeds are placed on a sieve plate covered with fine wire mesh in a temperature controlled (30–100 ±1°C) pressing chamber with a diameter of 30 mm. Pressures up to 100 MPa are exerted by a hydraulic plunger. The press is fitted with a thermocouple (±1°C), pressure sensor and a position transducer (±0.01 mm), which measures the distance the plunger traveled. Measured values are automatically recorded every second, [13]. Hydraulic presses were in use until the 1950s. They are replaced with continuous screw presses and continuous solvent extraction plants, which are less labor intensive. The olive oil industry still utilizes hydraulic press today.



(a) (b)

Figure 3: Equipments for oil expression: a. Hydraulic press, [13]; b. Screw press, [5]
1 – hydraulic unit; 2 – displacement sensor; 3 – support; 4 – plunger; 5 – seeds; 6 – filter medium; 7 – sieve plate; 8 – collection chamber; 9 – jacket; 10 – frame; 11 – needle valve; TI – thermocouple

The first screw oil press was developed in 1900 by V.D. Anderson in the United States. This press permitted continuous operation of hydraulic presses which resulted in greater capacities with smaller equipments and less labor, [4]. The mechanical screw press (fig. 3(b)) consists of a vertical feeder and a horizontal screw with increasing body diameter to exert pressure on the oilseeds as it advances along the length of the press. The barrel surrounding the screw has slots along its length, allowing the increasing internal pressure to first expel air and then drain the oil through the barrel. Oil is collected in a trough under the screw and the de-oiled cake is discharged at the end of the screw. The main advantage of the screw press is that large quantities of oilseeds can be processed with minimal labor, and it allows continuous oil extraction. [10].

Considerable efforts have been made in the past to improve the oil extraction efficiency of screw presses. Most of them have focused on optimization of process variables such as applied pressure, pressing temperature and moisture conditioning of the fed samples, [2]. Others improvements on oil screw presses was made for the design of the presses and for the material of presses construction.

To improve the cooking techniques, oil recovery and quality of oil and cake, an ***extruding-expelling (E-E) technology*** (fig. 4) have been adopted. This technology was applied by Nelson et al (1987) for extraction of oil from soybean. Extruding-expelling technology couples a dry extruder in which heat is generated by friction with continuous screw press. The coarsely ground whole soybean with 10-14% moisture content was extrusion cooked for less than 30 seconds at the temperature of 135°C and then was immediately pressed in a continuous screw press. The extrusion prior to expelling greatly increased the throughput of the expeller over the rated capacity, the expelled oil was remarkably stable and a press cake with 50% protein and 6% residual oil was obtained. To improve the cooking techniques, oil recovery and quality of oil and cake, some leading screw press manufacturers have developed more efficient extruders. Anderson Hivex, is a new screw press design which combines pre-pressing and extruded collets formation into a single processing unit. Thus, a drainage cage and a pressing screw are included into the barrel of an expander.

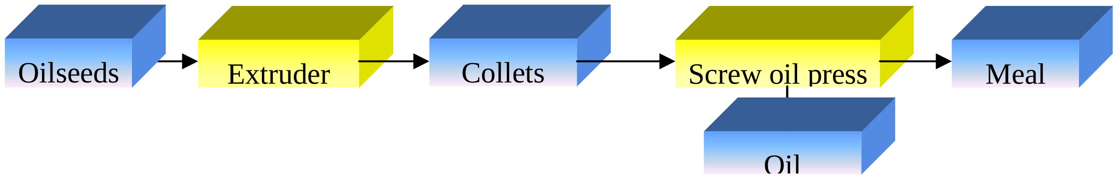


Figure 4: Flow diagram of an Extrusion-Expelling (E-E) technology, [10]

The chemical methods are another technology used for oil extraction from oilseeds. In the case of chemical methods, enzymes or solvents are used for the oil extraction, [12].

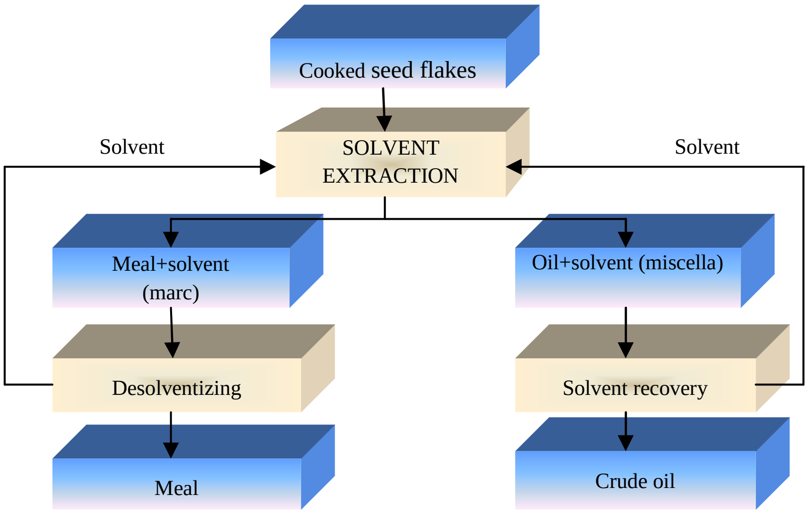


Figure 5: Flow diagram of solvent extraction method,[4]

Solvent extraction is the process of separating a liquid from a liquid-solid system with the use of a solvent. For oil extraction, the following light paraffinic petroleum fractions are used: pentane, hexane, heptanes and octanes. In solvent extraction, the seeds are first flaked (this operation is necessary in order to increase the contact area of the seed with the solvent, resulting in a increasing of the oil yield) and cooked (cooking denatures cell tissues so that solvent can penetrate the flakes more readily). After theses operations, the cooked seed flakes are mixed with the solvent in order to extract the oil. It results a mixture of oil and solvent, called miscella, which is heated in evaporators at 80°C. Steam is injected on the shell side to vaporize and reduce hexane to about 5% of the oil, then the oil is directly steam-stripped in a vacuum tower at temperatures rising to a final 110°C, [4]. This is the most efficient technique to recover oil from oilseed. It is expected that the residual oil in the meal to be less than 1% after commercial solvent extraction. There are, however, some limitations and disadvantages related to the solvent oil extraction: the chemical solvents are harmful to human health, the chemicals used are highly flammable and the danger of fire and explosion always exists, the initial capital and operating costs are high, the energy requirements are high and the quality of recovered oil is lower than that of pressed oil. In order to improve the solvent extraction efficiency and to reduce the processing cost, the extrusion process was used as a pretreatment of the oilseeds. The benefits obtained by using this pretreatment are the folowing: oil extraction rate increased, the amount of oilseed material present in the extractor increased, extractor capacity increased, steam requirement in the desolventizer reduced.

Another chemical method used for oil extraction from oilseeds is represented by ***extraction using enzymes***. This method is implemented by big vegetable oil companies because the process produces many high value products. The first step necessary is the cooking of the seeds and after that, the cooked sedds are put into water. The following step is the enzymes adding which digest the solid material. At the end, the separation of the residual enzymes and oil are made using a liquid-liquid centrifuge, [12].

Taking into account the concerns about environmental and human health hazards produced by the organic solvents and residues in oil, it was necessary the replacement of the solvents for edible oil extraction. Thus, the replacement of solvents with supercritical fluids (SCF) have been studied for more than two decades. The ***supercritical fluid extraction (SFE)*** is a technique similar to conventional solvent extraction, but the solvent is not a liquid but rather a gas above its critical point. Supercritical fluid used in oil extraction is CO_2, this being the supercritical fluid most used in analytical applications because it does not extract molecular oxygen and is not a toxic fluid. In the supercritical carbon dioxide technique, the seeds are mixed with high pressure carbon dioxide in liquid form (at 31°C temperature and 7,3 MPa pressure). Then, oil dissolves in the carbon dioxide. When pressure is released from the system, the carbon dioxide returns to the gas phase and oil precipitates out from CO_2-oil mixture. The extraction efficiency depends on the temperature, pressure, contact time between the extracting fluid and the oilseed material and the solubility of the oil in the extracting fluid, [10].

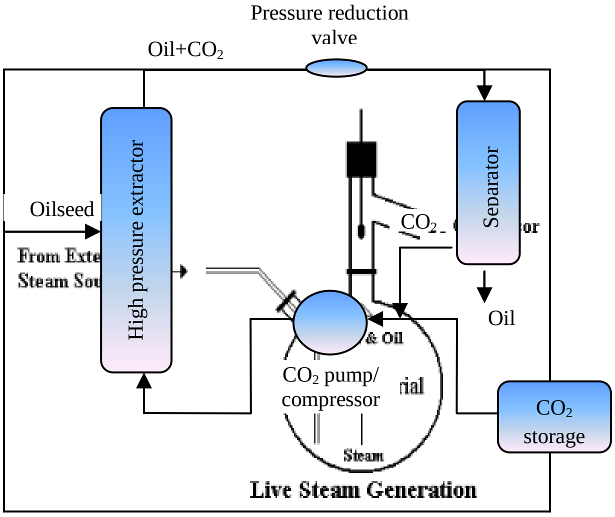


Figure 6: Flow diagram of a supercritical carbon dioxide extraction system, [10]

Figure 7: Distilling pot, [7]

SFE appears to be a cost-effective technique in laboratory scale, but an accurate economic evaluation for large-scale units requires supplementary experiments. The advantages of SFE-CO_2 extraction over the petrol ether extraction include: low operating temperature, hence no thermal degradation of most of the labile compounds; shorter extraction period; high selectivity in the extraction of compounds; no solvent residue with negative effects on the oils quality, [14].

The method of ***steam distillation*** is used for extraction of essential oils. Essential oils are the highly concentrated essences of aromatic plants used in healing of the body and the mind. When steam distillation is used in the manufacture and extraction of essential oils, the botanical material is placed in a still and steam is forced over the material.

The hot steam helps to release the aromatic molecules from the plant material since the steam forces open the pockets in which the oils are kept in the plant material. The molecules of these volatile oils then escape from the plant material and evaporate into the steam. The temperature of the steam needs to be carefully controlled - just enough to force the plant material to let go of the essential oil, yet not too hot as to burn the plant material or the essential oil. The steam which then contains the essential oil is passed through a cooling system to condense the steam, which form a liquid from which the essential oil and water is then separated. The steam is produced at greater pressure than the atmosphere and therefore boils at above 100°C which facilitates the removal of the essential oil from the plant material at a faster rate and in so doing prevents damage to the oil, [9].

3. CONCLUSIONS

This paper represents a review of actual methods used for obtaining vegetable oil from oilseeds. Studying the specialty literature, it was established that currently, worldwide there are four basic methods for obtaining vegetable oil: chemical extraction, supercritical fluid extraction, steam distillation and mechanical extraction. Taking into consideration the advantages and disadvantages presented by each method, the most used method for small scale production is mechanical pressing using screw presses, due to the simplicity of the process and equipments, the low investment cost and the high quality of the products. The main disadvantage presented by mechanical pressing is the higher residual oil quantity from the cake, comparing with the solvent extraction method.

References

[1]. Alonge A.F. and all, *"Effects of dilution ratio, water temperature and pressing time on oil yield from groundnut oil expression"*, Journal of Food Science and Technology, vol. 40, no.6, 652-655, 2003

[2]. Bamgboye A. and Adejumo A., *„Development of a sunflower oil expeller"*, Agricultural Engineering International: the CIGR Ejournal. Manuscript EE 06 015, vol IX, September 2007

[3]. Banu C., *"Manualul inginerului din industria alimentară"*, vol. I și II, Editura Tehnică, București, 1999

[4]. Bargale P.C., *"Mechanical oil expression from selected oilseeds under uniaxial compression"*, Ph.D. Thesis, University of Saskatchewan, Canada, 1997

[5]. Ferchau, E.,*"Equipment of Decentralized Cold Pressing of Oil Seeds"*, Webpage of Folkecenter For Renewable Energy, www.folkecenter.dk, 2000

[6]. http://facultate.regielive.ro/cursuri/industria-alimentara/industria-produselor-oleaginoase-64663.html

[7]. http://infohost.nmt.edu/~jaltig/SteamDistill.pdf

[8]. http://www.biblewalks.com/info/OilPresses.html

[9]. http://www.essentialoils.co.za/steam-distillation.htm

[10]. Nurhan D., "*Oil and Oilseed Processing II"*, Robert M. Kerr Food & Agricultural Products Center, FAPC-159

[11]. Owolarafe O.K. and all, *"Mathematical modeling and simulation of the hydraulic expression of oil from oil palm fruit"*, Biosystems Engineering 101, 331-340, 2008

[12]. Sari P., *„Preliminary design and construction of a prototype canola seed oil extraction machine"*, Ph.D. Thesis, Middle East Technical University, Ankara, Turkey, 2006

[13]. Willems P. and all, *"Hydraulic pressing of oilseeds: Experimental determination and modeling of yield and pressing rates"*, Journal of Food Engineering 89, 8-16, 2008

[14]. Xiao J.B. and all, *„Supercritical fluid CO_2 extraction of essential oil from Marchantia convoluta: global yields and extract chemical composition"*, Electronic Journal of Biotechnology ISSN: 0717-3458, vol. 10, no. 1, 2007