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Traditional And Novel Methods for Oil Extraction

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Summary

Oils are one of the major contributors of fat in our diet; it enhances palatability of food, shelf-life and makes food tasty. The method used for extraction of the oil is of paramount importance as it determines the quality of the final products and the possible environmental implications. It is obvious that the oil yield from oil-bearing agricultural products depends on the methods or techniques being adopted. There are various oil extraction methods with advantages and dis-advantages. Finding the best oil extraction method for particular oil-bearing agricultural product would increase the oil yield and quality.

1. Introduction

Oil extraction is the process of recovering oil from oil-bearing agricultural products through manual, mechanical, or chemical extraction. The agricultural products are classified into oil-seeds (cotton, castor, sunflower, etc), nuts (coconut, groundnut, sheanut, etc) and mesocarps or fruits (oil palm). Oil extracted from these products have diverse domestic and industrial uses. The oil serves as a major source of vegetable oil that constitutes a good percentage of meal in the diets of common people. The oil as well as the by-products are also very useful as food and non-food materials for the production of, cosmetics, detergent, plastics, etc. Oils and lipids are not only used in the food industries in manufacturing of edible products such as cake, margarine, biscuit, snacks but are also a major component in other nonedible applications such as cosmetics, varnishes, adhesives, lubricants, soaps, synthetic resins, greases, paints, and waxes, etc.

The method used for extraction of the oil is of paramount importance as it determines the quality of the final products and the possible environmental implications. Currently, both traditional and improved methods are being used either in full-scale or as pilot projects in extracting these oils and fats. The traditional method is usually a manual process and involves preliminary processing and hand pressing. The improved method consists of chemical extraction and mechanical expression. The chemical extraction method requires the use of organic solvents to recover the oil from the products. Mechanical method involves the application of pressure to already pre-treated oil-bearing products. It employs the use of devices like screw and hydraulic presses as a means of applying the pressure. Although processing of oil-seeds, nuts, and fruits for oil production is achieved by both traditional and improved techniques, oil extraction techniques have not changed significantly over the years as the bulk of this trade is still in the hands of rural women employing traditional systems only. In most of the developing countries, there has been a steady rise in the demand of edible oil both for domestic and industrial uses. Therefore, continuous review of existing oil extraction methods would reveal the current state of the art especially on aspects that require further improvement. This in turn will sensitize engineers towards developing better machines and techniques to increase both the quality and quantity of oil yield to meet the increasing demand.

2. Traditional Extraction

Oil-seeds (cotton, castor, sunflower, etc.) in most cases, are ground to a paste without removing the husk or outer covering. In some instances, sunflower seeds are husked. The seeds are ground manually and the paste is heated alone at first and then with boiling water. The mixture is stirred and brought to boil. After boiling, the mixture is allowed to cool and the oil settles at the top and is scooped off. With this method of processing, the extraction efficiency is about 40%. The processing methods of oil-nuts vary because of the variation in the procedures. The most common oil-nuts grown in most countries are groundnuts and coconuts. Groundnuts are shelled, cleaned and roasted lightly. The roasted nuts are skinned by placing them on a mat and rolling a wooden block over them, and winnowing them to separate the skin from the nuts. The skinned nuts may be pounded with a mortar and pestle or ground using grinding stones to a smooth paste. The paste is kneaded and pressed by hand to remove the oil-water mixture. Then the oil-water mixture is fried to remove most of the water.

3. Mechanical Extraction

Mechanical method involves the application of pressure to already pre-treated oil-bearing products. There are two devices in extracting oil mechanically, those are hydraulic press and screw press.

3.1. Hydraulic press extraction

Hydraulic pressing is a natural and efficient method for extracting high-quality oil from seeds, nuts, and fruits. Unlike traditional methods that use heat and chemicals, hydraulic pressing uses pressure to extract oil while maintaining the oil's natural flavor, aroma, and nutrients. The hydraulic press machine operates based on the Pascal principle. It is composed of a hydraulic

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system including a hydraulic cylinder, piston, and hydraulic pipes. Oilseeds were milled, cooked, and wrapped in filter cloths woven from horsehair. The oilseeds wrapped in filter cloths were manually loaded into perforated, horizontal boxes below the head block and above the ram of the press. The boxes were pressed together using upward hydraulic pressure on the ram. The oil was pressed out through the filter cloths surrounding the oilseeds. The filter cloths and spent cake were manually removed from the hydraulic press. The residual oil in spent cake was approximately 10%. Which is specially designed in a compact structure for domestic and small oil mill use; offers pure and high-quality edible oil. Widely applied to press sesame, walnut kernels, kiwi seeds, almonds, etc.

3.2. Screw press extraction

The mechanical screw press was a radical departure and significant technological advancement over the hydraulic presses being used at the time. The mechanical screw press used a vertical feeder and a horizontal screw with increasing body diameter to impart pressure on the oilseed material as it proceeded along the length of the screw. The barrel surrounding the screw was slotted along its length, allowing the increasing internal pressure to first expel air and then expel the oil through the barrel. The expelled oil was collected in a trough under the screw, and the de-oiled cake was discharged at the end of the screw. Screw press oil extrusion machine used for extracting edible oil from more than twenty kinds of oilseeds such as peanut, soybean, flaxseed, sunflower seed, rapeseed, etc. The primary advantage of the mechanical screw press was that it allowed continuous oil extraction and could process large quantities of oilseed materials with minimal labor. The quantity of heat from friction drag satisfies technology in the pressing, which will contribute to thermal denaturation of protein in the raw material, and improve the oil extracting rate meantime.

4. Solvent Extraction

Solvent extraction is the process of separation of desirable component from a solid using a liquid solvent and is one of the modern extraction processes. Apart from mechanical and hydraulic expression, other techniques entirely rely on solvents in which the oil is dissolved and later separated through evaporation and distillation. Different solvent extraction techniques used in extracting oil from oil-bearing agricultural products are Soxhlet extraction, aqueous enzymatic extraction, microwave-assisted extraction, ultrasound-assisted extraction, supercritical fluid technology, high pressure-assisted extraction, and pulsed electric field-assisted extraction.

4.1 Soxhlet extraction

Soxhlet extraction is the most conventional method used to extract oils, phenolics and

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other secondary metabolites from plants. In SE, phenolics are extracted from the plant biomass by means of solubilization in the solvent. The SE technique is very simple and requires a Soxhlet unit, a thimble (normally made from cellulose) to contain the sample, and a percolator to circulate solvent through the sample (a circulating water bath connected to the Soxhlet unit and a heating mantle). An advantage of using SE is that a filtration step to recover the solvent containing extracted phenolics is not required because the plant residue is contained in the thimble and not mixed in directly with the solvent. Normally the SE process is carried over a 2-12 h period, commonly using a 40%–60% ethanol or methanol in water solution as solvent at reflux.

4.2 Microwave assisted extraction

Microwave-assisted extraction (MAE) is a trending extraction technique considered to have high throughput and extraction efficiency when compared to other conventional methods. MAE relies on a microwave generator that delivers microwave energy to a polarizable material consisting of the solvent and the oil-bearing material. Microwave radiations interact with dipoles present in the sample matrix causing them to oscillate in response to the changing electromagnetic fields. The oscillation/rotation of the dipoles generates heat on the surface of the material and the heat is further transferred to the inside of the material by conduction. Besides the dipoles from the solvent used in the extraction process, microwave radiations interact with the water present within the cells of the oil-bearing material resulting into a quick and uniform penetration of the heat to the target tissues. This heat results in the formation of water vapor and electroporation effects, which disrupts the cell wall of the oilseed and enhances efficient extraction of intracellular metabolites. Microwave radiation is a noncontact source of energy; hence, it provides effective heating, minimized thermal gradient, and selective heating when needed. Accordingly, extraction time is considerably reduced, uses less volume of solvent, accommodates both polar and nonpolar solvents, increases yield with good reproducibility, and yields superior sensory attributes in products.

4.3 Aqueous enzymatic extraction

Aqueous extraction is a traditional technique that uses water as a solvent to extract oil from oleaginous materials. Because water takes long to degrade the cell wall of oil-bearing material, the process is less effective and results in low yield. To counter this limitation, aqueous enzymatic extraction (AEE) uses both water and enzymes to degrade the cell wall network of the oil-bearing material, thereby allowing for the transfer of intercellular contents. Further, the cell wall of plant materials is composed of cellulose, hemicellulose, and pectin all of which can easily be broken down by the wide range of commercially available enzymes. Because the lipid molecules are amphipathic, only the water-soluble portion diffuses into the water, while the other

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components culminate into an emulsion. The oil is further de-emulsified either by the application of enzymes that dissolves it or by changing the temperature of the emulsion. AEE portrays tremendous potential as it can extract oil and proteins simultaneously owing to the insolubility of water in oil as well as segregation and recovery of desired compounds without any damage. The final products are highly suitable for human consumption when compared to other extraction methods and the oil obtained from enzyme-assisted extraction portrays superior quality properties. AEE is considered the most environmentally friendly process as it reduces the chemical load generated by organic solvents. However, its success heavily lies on a good understanding of the architecture of the oilseed.

4.4 Ultrasound-assisted extraction

Ultrasound-assisted extraction (UAE) has gained popularity in recent years because of its ability to improve the efficacy of various processes. As a green and novel extraction technique, it is highly scalable as far as the extraction of oil and other bioactive compounds is concerned. Its extraction mechanism is attributed to the production of cavitation bubbles, vibration, mixing, and pulverization among other complex mechanical effects. Collectively, the processes disrupt the cell wall, increase the permeability of the cell wall, and intensifies the rate of mass transfer. Propagation of ultrasound waves at a specific critical value in liquids creates a negative pressure in the fluid and consequently results in cavitation. The negative pressure develops when compression and expansion cycles of the ultrasound waves exceed the local tensile strength of the liquid. This phenomenon yields many tiny bubbles that grow with time to a point where they induce shear forces and turbulence as they collapse. The effective frequency range for this technique is 20 to 50 kHz. Cavitation, thermal, and mechanical effects are the prime cell wall degrading mechanisms during extraction and the combination of the three effects causes rupturing of the cell wall. Further, they increase the rate of chemical reactions and reduce the size of the particles. These synergistic effects account for the reduced extraction time and facilitate mass transfer without significantly damaging the extracts.

4.5 Supercritical fluid extraction

Supercritical fluid extraction (SCFE) technology uses supercritical fluid at vapor-liquid critical point to extract oil and other plant components. The supercritical state is only achieved when the solvent is subjected to temperature and pressure beyond its critical point. At the critical point, there is no distinctive gas or liquid phase and the solvent behaves more like a gas with solvating properties of a liquid. The gas-like viscosity on the other hand results in high rates of mass transfer. Commonly used solvent is carbon dioxide (CO_2) because it is inert, abundant, non-inflammable, nontoxic, possess moderate critical properties, and can easily be recovered from the reaction streams. The extraction process requires less time, is highly selective, and is environmentally friendly because it does not use organic solvents. The principal merit of this technique is that no follow-up separation steps are required to obtain the oil from the substrate mixture. The efficacy of SCFE extraction heavily depends on the intrinsic and extrinsic factors to the process. In spite of having a simple extraction process, application of SCFE technology is limited due to high equipment cost.

4.6 Pulsed electric field-assisted extraction

Pulse electric field (PEF)-assisted extraction is a groundbreaking nonthermal technology that is used to improve the extraction efficiency of vegetable oil from various oilseeds. The technology involves the discharge of direct electric pulses into the oleaginous material for a short duration of time (microseconds to milliseconds) and high voltage, up to 50 kV. The oil-bearing material is placed between a high voltage electrode and a grounded electrode. The electric pulses traverse through the cell membrane and generate electric fields (up to 10 kV/cm), which disintegrates the membrane molecules based on their net charge. The separation of membrane molecules results in the formation of pores and increases the permeability of the cell wall of the plant tissues. Consequently, the diffusion of solutes through the cell wall is enhanced by electroporation, and this favors the extraction of intracellular substances like oil and other components of interest. Pulse duration and pulse interval are the two fundamental factors affecting the effectiveness of PEF treatment. As an emerging physical technology, it improves mass transfer processes, and PEF pretreatment on crushed oilseeds increases oil yield and recovery of bioactive compounds.

4.7 High pressure-assisted extraction

High pressure-assisted extraction (HPAE) is rather new and superior compared to other extraction techniques because it avoids heating of the substrate, and thus preserves the properties of the bioactive compounds and other biological activities. Depending on the intensity of the applied pressure, the process can be categorized as high pressure (above 100 MPa), medium to high-pressure process (10 to 100 MPa), and low pressure (below 10 MPa). With regard to the operating temperature, the process can also be categorized as pressurized liquid extraction (low temperature) or pressurized hot water extraction if the temperature is high. The applied pressure disrupts the plant tissues, interrupts the cell wall and the cell membrane, and facilitates the transfer of the soluble matters between the solvent and the substrate. The fundamental theory behind HPAE is the phase behavior theory, which dictates that solubility of a substance is enhanced at higher pressure. Under the pressurized condition, the solvent permeates more rapidly through the cells, contacts cellular constituents, and actively dissolves the target components in a short time.

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HPAE offers several advantages such as prevention of thermal degradation of food constituents, acts rapidly and uniformly over the substrate, retains high bioactivity by maintaining covalent bonds, requires less time, and gives a high oil yield compared to most extraction techniques.

Conclusion

Different oil extraction methods and technologies have been reviewed. It is obvious that the quality of oil and its yield from oil-bearing agricultural products depends on the methods or techniques being adopted. Each method has unique advantage over other, and selection of particular method completely depends on the nature of the agricultural products and feasibility of the method. The implementation of improved and feasible extraction methods would increase the oil quality and yield.

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