International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

# A Review of Methods Used for Seed Oil Extraction

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***Abstract:*** ***Seed oils have found application as food (edible oil), and generally as raw materials for the synthesis of biobased polyols, polymers, resins, fuels, soaps and detergents, lubricants and other products of the chemical industry. Consequently, a lot of attention is being paid to these biodegradable, renewable bioresources of plant origin as potential candidates for the replacement of costly and environmentally unsafe chemical feedstock of fossil origin. Oilseeds represent a green or natural reservoir from which these resources can be harnessed and utilized as platform chemicals at laboratory and industrial scales on a sustainable basis. In this review, old traditional methods, well-known and widely practiced conventional methods, and new, innovative methods of seed oil extraction are brought to focus and compared in terms of oil yield and oil recovery, as well as oil purity and quality. The merits and demerits of these methods are highlighted. More importantly, process control measures towards raising and optimizing oil yield and improving oil quality are discussed. Literature review and analysis has shown that oilseed pretreatment prior to oil extraction is a very important step towards achieving good oil yield and quality. Ultimately, the selection of suitable extraction method (s) may also depend on whether small or large scale oil extraction is intended. It is hoped that this review would be useful to stakeholders in seed oil prospecting and exploitation, notably oilseed researchers and oilseed processors, in selecting the most suitable methods of oil extraction.***

**Keywords:** Seed oil, extraction, methods, yield, quality

## 1. Introduction

The vast majority of plants, especially the agricultural stock, contain extractable oil that may be of some commercial value. Since the beginning of human civilization, rural communities from around the globe have used various traditional methods to extract mainly edible oil from materials of plant origin. Many edible vegetable oils such as palm, corn, soybean, peanut, coconut etc (CODEX-STAN 210-1999) are used as table oils because of their high nutritive value. For instance, fats and oils are the most concentrated form of energy, providing approximately 9 kcal of energy per gram compared to only 4 kcal per gram for proteins and carbohydrates (Ali *et al.*, 2005). This is in addition to their industrial application as raw materials for the synthesis of polyols, polymers, resins, biodiesel, pharmaceuticals etc.

With regard to industrial application, focus ought to be more on non-edible oils like castor and jatropha oils, while preserving the edible ones for human consumption. Current global vegetable oil consumption (2016/2017) stands at around 182 million metric tons (Statista, 2018). The rising demand for vegetable oils both for human consumption and industrial application has prompted and encouraged the evolution and optimization of procedures leading to efficient production of oil of high quality and purity (Kyari, 2008; Patel *et al.*, 2016). Key issues arising from the exploitation of oleaginous materials of plant origin are: how much oil do they contain; how much of this oil can be extracted or recovered (% oil yield or % oil recovery), and what is the purity and quality of the extracted oil? With the exception of palm and olive oils which are extracted from their fruits (Ali *et al.*, 2005), most vegetable oils are extracted from oilseeds. Consequently, seed oils have continued to attract enormous attention as potential source of platform chemicals at both laboratory and industrial scale (Sharmin *et al.*, 2012). Nonetheless, seed oil yield will depend among others on oil seed variety, soil and environmental conditions around the resource oil-bearing plant, as well as on pretreatment procedure, and the particular extraction method (s) used.

In terms of composition, triacylglycerols (TAGs) are the major chemical constituents of fats and oils. Unlike animal oils that are made up of mainly saturated fatty acids (SFAs), vegetable oils (with the exception of coconut and palm kernel oils that are predominantly made up of saturated FAs) contain varying proportions of saturated and unsaturated fatty acids (UFAs) tied in their TAG molecules. The UFAs may be monounsaturated (MUFAs) or polyunsaturated (PUFAs). The physico-chemical properties of TAGs are largely dependent on the nature of their constituent fatty acids (FAs), and this varies from oil to oil. Simple TAGs contain same FA in their molecules, whereas mixed TAGs contain two or three different FAs in their molecules.

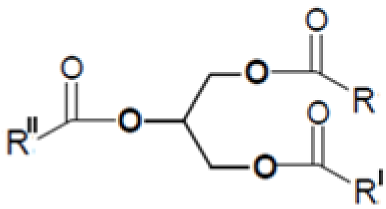


**Figure 1:** Structure of a typical plant oil TAG

## 2. Oilseed Pretreatment

Irrespective of the extraction method to be used, oilseed pretreatment is necessary. Basic steps in this process are dehulling, pod or seed coat removal, winnowing, sorting, cleaning, grinding or milling and preheating (Ogunniyi, 2006; Yusuf *et al.*, 2015). Grinding or crushing of oilseeds prior to extraction is to ensure that oil-bearing minute cells embedded in fibrous structures are broken or ruptured to release the oil (Akpan *et al.*, 2006; Tayde *et al.*, 2011). Heat treatment further facilitates the oil release process by reducing moisture content and hardening the interior of the oilseed (Patel *et al.*, 2016). In recent times, preheating of oilseed done conventionally by hot air oven, is being replaced by microwave-assisted heat treatment, the latter offering some advantages (Mgudu *et al.*, 2012). Additionally, grinding or size reduction prior to solvent extraction increases the surface area for solvent penetration to bring out the oil by leaching.

Oil yield from an oleaginous seed material is generally dependent on the quality of oilseeds. However, there are certain factors like moisture content of material, particle size and temperature that can be manipulated during pretreatment in order to maximize oil yield. According to Olaniyan (2010), oilseed pretreatment prior to oil extraction normally affects oil yield and quality. Similarly, Faugno *et al*. (2016) who carried out the analysis of main extraction parameters on yield of mechanically pressed tobacco (*Nicotiana tabacum* L) seed oil found that the combination of seed preheating and high extraction temperature, among others, had a significant effect on oil yield. Thus oilseed processing or pretreatment provides an avenue for manipulating key parameters and conditions for enhanced oil yield and quality.

## 3. Review of Oil Extraction Methods

### 3.1 Old Traditional Methods

In terms of oil recovery and oil yield, the old traditional or informal wet extraction methods used by rural communities around the globe is regarded as inefficient, often yielding below the range of plant oil content found in literature (Alonge and Olaniyan, 2006; Olaniyan, 2010).

Olaniyan (2010) has outlined three major means of recovering oil from oleaginous materials of plant origin as wet extraction (hot water or steam extraction), solvent extraction and mechanical expression. With regard to the wet extraction method, Oluwole *et al*. (2012) proffered nine major operations that are involved in the extraction of castor oil by the old traditional method namely, collection of seed pods, shelling of the pods/winnowing, boiling the seeds to reduce moisture, grinding of seeds to form paste, mixing the paste with water/boiling to extract oil, scooping of oil and drying the oil by heating. They evaluated the percentage yield (19.42) and percentage oil recovery (38.84) using the expressions

$$\% \text{ oil yield} = \frac{Moil}{Mseed} \times 100 \qquad (1)$$

$$\% \text{ oil recovery} = \frac{Moil}{XMseed} \times 100 \qquad (2)$$

Where Moil = mass of oil (kg)
Mseed= mass of oilseed (kg)
X = oil content of oil seed

Olaniyan and Yusuf (2012) described the old traditional method of extraction of seed oils as involving the roasting of seed kernels by mortar and pestle or between two stones, mixing the crushed mass with water, cooking of the mixed paste in order to obtain the oil by floating and skimming, and then drying of the oil by further heating. They further described this method as tedious, time consuming, energy sapping, drudgery prone, inefficient and low in yield and quality. In other words, the old traditional methods are crude, largely unscientific, inefficient, and yielding poor quality extracted oil.

### 3.2 Conventional Methods

The conventional methods are the well-known and widely practiced methods of oil extraction namely, solvent extraction and mechanical expression. Many seed oils are extracted by either of the two methods, or a combination of the two. This classification may also include rendering (Ali *et al*., 2005), though perhaps not as widely used. Regardless of extraction method, extracted and refined oil must be evaluated for its physico-chemical properties to determine its application or usage.

#### 3.2.1 Solvent extraction

The solvent extraction method is a conventional extraction method commonly applied to oilseeds with low oil content (< 20%), like soybean. This method is considered as one of the most efficient methods in vegetable oil extraction, with less residual oil left in the cake or meal (Buenrostro and Lopez-Munguia, 1986; Tayde *et al*., 2011). The choice of solvent is based mainly on the maximum leaching characteristics of the desired solute substrate (Dutta *et al*., 2015). Solvents commonly used are hexane, diethyl ether, petroleum ether and ethanol. Other considerations are high solvent-solute ratio, relative volatility of solvent to oil, oil viscosity and polarity, as well as cost and market availability (Muzenda *et al*., 2012; Takadas and Doker, 2017).

The solvent extraction method offers a number of advantages. Bhuiya *et al*. (2015) who researched on the optimization of oil extraction process from Australian Native Beauty Leaf Seed (*Calophyllum innophyllum*) reported that the solvent extraction process is a very effective method, with high yield and consistent performance, though cost of production was relatively higher than mechanical press methods due to high cost of solvent. According to Muzenda *et al*. (2012) in their work on the optimization of process parameters for castor oil production, they observed that oil extraction ability of solvent during solvent extraction is enhanced with increase in extraction time; with solvent-solute ratio in favour of the solvent preferably by a factor of 6:1. Ikya *et al*. (2013) studied the effects of extraction methods on the yield and quality characteristics of oils from shea nut. They compared results of physical, chemical and sensory properties of oil extracted by solvent extraction and old traditional extraction methods. They reported a higher oil yield of 47.5% for the solvent extraction method compared to 34.1% for the old traditional method, and better keeping quality for the solvent-extracted oil (lower moisture content and lower flash and fire point values). In their work on the extraction, characterization and modification of castor seed oil, Akpan *et al*. (2006) employed the solvent extraction method to extract castor seed oil from castor bean paste using Soxhlet extractor. They obtained 33.2% oil yield, which was within the expected range for castor beans found in literature. They concluded that mode of extraction and seed variety are very important parameters affecting oil yield.

Other advantages are its repeatability and reproducibility. However, this method has some industrial disadvantages such as long extraction times, relatively high solvent consumption, high investment, high energy requirement, plant security problems, emission of volatile organic compounds into the atmosphere, high operation costs, poor product quality caused by high processing temperatures and a relatively high number of processing steps (Buenrostro and Lopez-Munguia, 1986; Del Valle and Aguilera, 1999; Dawidowicz *et al*., 2008; Takadas and Doker, 2017).

Additionally, the process makes use of organic solvents whose removal brings additional cost and labour (Gibbins *et al.*, 2012).

Soxhlet based solvent extraction process is the primary means of extracting vegetable oil from oleaginous materials. The Soxhlet process is widely used in laboratory scale oil extraction (Abdelaziz *et al.*, 2014), but large scale operation of this process would require a commercial solvent extractor (Ogunniyi, 2006). The major advantage of the Soxhlet process is solvent recycling (over and over) during extraction. However, disadvantages of the Soxhlet method include high solvent requirement, time and energy consumption (Takadas and Doker, 2017), as well as sample being diluted in large volumes of solvent (Rassem *et al.*, 2016).

**3.2.2 Mechanical expression**

Mechanical expression involves the application of pressure (using hydraulic or screw presses) to force oil out of an oil-bearing material (Arisanu, 2013). By this method, oil yield is enhanced by increased mechanical pressure on the oil-bearing material. In a study of the yield characteristics of ground soybean sample at various operating pressures, pressing durations and product bulk temperatures, Mwithiga and Moriasi (2007) found that oil yields increased linearly with compression pressure (40-80 $kgf/m^2$ ), duration of pressing (6-12 mins) and increase in the bulk temperature of preheated oilseeds, reaching a peak yield at about $75^0$C.

With regard to oil yield, screw presses have an advantage over hydraulic presses for churning out slightly higher yields, in addition to their continuous mode of operation (Arisanu, 2013). Mechanical presses (manual or powered) meant for small (laboratory) scale oil extraction are simple, safer and containing fewer steps compared to solvent extraction of vegetable oils (Oyinlola *et al*., 2004). However, in developing countries even simpler devices are in use to achieve similar results (Mwithiga and Moriasi, 2007). On the industrial scale, industrial machines or expellers are used for the purpose of extracting vegetable oils mechanically.

Mechanical press methods are often used to extract vegetable oil from oilseeds having oil content higher than 20% (Sinha *et al*., 2015). Generally, these methods have the advantage of low operation cost, and of producing high quality light coloured oil with low concentration of free fatty acids (FFAs) (Carr, 1976; Kirk-othmer, 1979). However, it has a relatively low yield compared to solvent extraction and is therefore comparatively inefficient, often with a large portion of oil left in the cake or meal after extraction (Buenrostro and Lopez-Munguia, 1986; Anderson, 1996). In addition, it is time consuming and labour intensive (Bhuiya *et al*., 2015). In castor oil extraction for instance, mechanical pressing removes only about 45% of the oil, with remaining oil in meal extractable by solvent extraction method (Ogunniyi, 2006).

There are two types of mechanical press methods namely, cold-press and hot-press methods. Cold-press or scarification method is carried out at low temperature (below $50^0$C) and pressure, whereas the hot-press method is carried out at elevated temperature and pressure. Cold-pressed seed oils are safer than hot-pressed seed oils as adverse effects caused by high temperatures are avoided in the former. Some of the likely adverse effects are decreased oxidative stability, degradation of valuable oil components and reduced oil keeping quality. In cold-pressed oils, the purity and natural properties of seed oils are preserved (Azadmard-Damirchi *et al*., 2011; Bhatol, 2013). This includes the retention of valuable nutraceuticals like phytosterols and tocopherols in the extracted oil (Kittiphoom *et al*., 2015). Because of these attractive qualities, there is growing global demand for cold-pressed oil. In contrast, hot-press methods give higher oil yield due largely to decreased seed oil viscosity at high temperatures. This enhances oil flow during extraction. Thus high temperature increases the efficiency of the extraction process and yields of up to 80% of available oil in seed are possible (Patel *et al*., 2016), but they may also engender oil degradation, with attendant deterioration of oil quality.

## 4. Innovative Techniques

Conventional methods for oil extraction are time and solvent consuming, in addition to being thermally unsafe. These shortcomings can be overcome by the use of alternative innovative methods such as microwave-assisted extraction (MAE), ultrasonic-assisted extraction (UAE), supercritical fluid extraction (SFE), soxtec extraction etc. (Bampouli *et al*., 2014).

**4.1 Microwave-assisted extraction (MAE)**

MAE is one of the innovative techniques for isolating vegetable oils from oilseeds. It is also used in the extraction of essential oils (Ramanadhan, 2005; Rassem *et al*., 2016). The method is simple, but superior to many other thermal methods used for the purpose of extracting high quality vegetable oils. Pretreatment of oilseed is done in the microwave oven, which uses radio waves to convey energy and convert it to heat at a frequency range of about 300 MHz to 300GHz (Singh and Heldman, 2001). The use of microwave radiation in oilseeds results in the rupture of cell membranes, making it possible to obtain higher extraction yield and an increase in mass transfer coefficients (Azadmard-Damirchi *et al*., 2011).

MAE has been applied with increasing success in oil extraction. Moreno *et al*. (2003) used microwave pretreatment to oil extraction from avocado, and found that extract efficiency was 97% Soxhlet-hexane extraction coupled with microwave pretreatment when compared with only the neat Soxhlet-hexane extraction (54%). In terms of quality of microwave extracted oil, Veldsink *et al*. (1999) reported that oil extracted from microwave treated rapeseed showed a markedly improved oxidative stability, most likely due to increase in phenolic antioxidants. Similarly, Balasubramanian *et al*. (2010) found that microwave pretreated oil had a higher composition of unsaturated and essential fatty acids (FAs), thus a better oil quality. They also reported better extraction rates, high oil yields and good oil quality for the microwave extraction process. Indeed, this technique has been used for the extraction of oil from a wide variety of oilseeds including soybean, castor, peanut, canola, olive, sunflower, hazelnuts, rapeseed etc. (Mgudu *et al*., 2012).

Kittiphoom *et al*. (2015) investigated the effect of microwave radiation (2450 MHz), at different treatment times of 0-150 seconds, on mango seed as substrate pretreatment prior to oil extraction by the Soxhlet method. They noted the major advantage of this method over conventional methods as reduced extraction time and reduced energy consumption costs. Mgudu *et al*. (2012) who carried out microwave pretreatment of castor beans prior to solvent extraction obtained relatively high oil recoveries of up to 44.34% yield at 280W microwave irradiation, for 120 seconds. Advantages of this method include (Ramanadhan, 2005; Azadmard-Damirchi *et al*., 2011):

- Improving oil extraction yield and quality
- Direct extraction capability
- Lower energy consumption
- Faster processing time
- Reduced solvent consumption

The technique also allows for better retention and availability of desirable nutraceuticals such as phytosterols and tocopherols, canolol and phenolic compounds in the extracted oil. It therefore represents a new step forward for the production of nutritional vegetable oils with improved shelf life because of high antioxidant content.

One disadvantage of MAE is that it may not always be suitable for plants, since high microwave energy disrupts plant structure (Uquiche *et al*., 2008). Moreover, MAE would degrade the polyunsaturated FAs (PUFAs) in vegetable oil, resulting in unrepresentative FA profile. One problem associated with applied high temperatures during oil extraction is that they may engender degradation reactions that can impair oil quality. This is more so where oil extraction time is long. However, despite claims that short exposure time to microwaves as compared to oven heating preserves most thermolabile compounds from degradation reactions (Amarni and Kadi, 2009), to-date there have not been comprehensive evaluations on the safety levels of microwave irradiations, especially as they relate to edible oils meant for human consumption.

### 4.2 Ultrasonic-assisted extraction (UAE)

UAE is a new innovative technique which makes use of ultrasonic sound waves to increase vibration and heat, resulting in the destruction of rigid plant cell walls, thereby enhancing contact between solvent and the plant material (Takadas and Doker, 2017). When coupled with solvent extraction, the UAE method represents an innovative way of increasing extracted oil yield by making plant cell walls thinner, and thus enhancing the interaction of the solvent. This technique has been applied by a number of researchers. Samaram *et al*. (2014) analyzed oil production from papaya seeds by both UAE and solvent extraction. They reported that conventional solvent extraction lasted 12 hours, whereas the UAE method lasted only 30 minutes. This makes the UAE more suitable in terms of reduced time lag and yield. Li *et al*. (2004) studied oil production from soybean by the UAE method, using hexane as solvent. They suggested that UAE has the potential to be used in oil extraction processes to improve efficiency and reduce the process time, which may have a significant impact on edible oil industry.

The good performance of these innovative techniques has in recent years encouraged researchers to explore the prospects of combining some of them, with the aim of synergizing oil extraction. Chemat *et al*. (2003) tried a combined ultrasound and microwave pretreatment method for the extraction of essential oil from caraway seeds. They found that significant improvement in extraction was obtained using simultaneous ultrasound and microwave pretreatment. Advantages of the UAE method include:

- Reduction in extraction time (Stanisavljevic *et al*., 2007)
- Lower energy consumption and being ecofriendly (Tian *et al*., 2013; Hashemi *et al*., 2015)
- Increased extraction yield and higher processing throughout (Takadas and Doker, 2017).

### 4.3 Others

Other innovative techniques for the extraction of oilseeds (as well as essential oils) include supercritical fluid extraction (SFE) (Zhi-ling *et al*., 2011), microwave-assisted hydrodistillation (MAHD) (Lucchesi *et al*., 2004; Ferhat *et al*., 2006), pressurized liquid extraction (Danlami *et al*., 2014), soxtec (Bampouli *et al*., 2014) and a host of others. These methods, together with MAE and UAE, have been successfully used to effectively reduce the major shortcomings of the conventional methods of oil extraction.

## 5. Conclusion

This work has reviewed well-known and widely practiced methods of seed oil extraction namely, old traditional methods, conventional methods (solvent extraction and mechanical expression), as well as new innovative methods aimed at raising and optimizing oil yield and improving oil quality. The old traditional methods were largely crude and inefficient. Major shortcomings associated with the conventional methods are extraction time lag, solvent consumption and adverse thermal effects at high temperatures. However, new innovative techniques such as microwave-assisted extraction (MAE), ultrasonic-assisted extraction (UAE), supercritical fluid extraction (SFE) etc have been developed, and are being used to effectively reduce these shortcomings.

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