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Producing High Quality Edible Oil by using Eco-Friendly Technology: A Review

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Abstract: Development of health and environmental issues specifically related to the use of chemical ingredients in foods both in producing processes and as a preservative agent has encouraged the emergence of non-chemically processed products on the market. This condition is predicted to continue increasing with high market response. This review will discuss some developments, surrounding the edible oil extraction and purification technology, including some alternative to substitute conventional solvent extraction in order to produce a chemically free edible oil product. Enzymatic and ultrasound assisted/pre-treatment in aqueous, cold pressing and supercritical fluid extraction will be highlighted, as well as adsorptive refining and other processes as an alternative for purification technology.

Key words: Adsorptive, aqueous extraction, cold pressing, environmental friendly, enzymatic, ultrasound

INTRODUCTION

Fat/oil has become an integral part of human diet. According to Food and Agriculture Organization (FAO, 2003), per capita fat consumption has increased significantly, from an average of only 53 grams in 1967-1969 to as much as 73 g/capita/day in 1997-1999 around the world and contributes 30% of total energy supply of mankind. It is also projected to continue growing. The increase in oil production -which began with the application of solvent extraction method- made the access to these commodities easier. The increasing income in developing countries (WHO, 2003) and the emergence of various health issues that eliminate previous cynicism towards oil and fat products also contributed to this improvement.

In general, extraction of oils and fats are done using three main ways, namely rendering (wet/dry), mechanical pressing and using a solvent extraction (Kiple and Ornelas, 2000). Rendering method is the oldest method used by humans, and often referred to as a traditional method (Ketaren, 1986). Large-scale oil development started when a mechanical pressing method was applied, and reached its peak 120 years ago when solvents were initially introduced for oil extraction (Matthäus, 2008).

Currently, edible oil products generally undergo a process of purification by using these methods; degumming, neutralizing, bleaching and deodorizing to produce uniformity in good quality oil. At this stage, the minor components are either physically or chemically separated because it is considered as impurities and will destabilize the oil in the next usage (Mc-Williams, 2001). Despite that, there are also products that maintain this component as it is medically useful for both, health and economical profitability. These products are usually referred to virgin oil products, whereas the aforementioned is referred to as refined oil (CAC, 2001).

The development of health issues and the increasing awareness of the environment that has become more frequent recently, urged the existence of healthy, free of chemicals and clean-methods for obtaining produce. The effect of this sentiment can be seen on the market today. The development of less-processed products and less or non-purified products while still retaining much of its original content has grown rapidly, to the extent that these products became popular because it has been shown to have many advantages. Various developments in the field of oil extraction and purification technology that support it have also been much studied. This review will discuss the development of extraction and purification technology of oil/fat, which refers to the eco-friendly technology and its development potential compared to the already implemented technology now present.

SOLVENT-FREE EDIBLE OIL EXTRACTION

Aqueous extraction: Among the three types of extraction that are commonly used, rendering is the earliest method used by humans. The main principle of this method, either wet or dry is by disrupting the tissue of the material by applying heat to allow oil separation. Dry rendering is done by heating a material so that the fat melts out and can be separated (Mc-Williams, 2001). Wet rendering in term of aqueous extraction, containing three important processes; material crushing, cooking process -which at first development is using heated water- and oil separation either using a pressing or centrifuging (Kiple, 2000).

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Low quality of oil produced and inefficiency in the application of materials are the reasons why this method is displaced by the other methods (Kiple, 2000). Through subsequent developments, the use of dry or wet steam, sometimes done under pressure, is used to improve the performance of the process (Kiple, 2000). However, it is still not as effective as the results produced by other methods, especially when compared to solvent extraction method. The advantage of using this method is, of course, related to the yield and flexibility of this method which can be applied to almost all materials. Many options of solvent and the variations of the results make it thoroughly highlighted. Hexane is the most widely used solvent today. Soybean and cottonseed oil is extracted using hexane, which is then distilled and reused. The high volatility of the solvent makes this method leave little to almost none of the residue in the product (Lawson, 1995).

Even though this method was initially ineffective, the market needs for the less-processed products and processed with little or no chemicals, made this method rise again (Matthäus, 2008). Many studies have been carried out to improve the efficiency of this process. In wet rendering method, the development is done mainly on malaxation treatment. Malaxation is generally done by boiling the solution or heating it with steam (Mc-Williams, 2001). This method produced higher yields, but also caused minor compound damage to the components. Particularly, using higher temperature resulted in degradation of flavour and aroma in olive, giving it the heated or burnt odour (Boselli *et al*., 2009). To tackle this issue, methods were developed using low temperature processes (Angerosa *et al.*, 2000; Wong *et al*., 2010), where these methods are mostly used to produce virgin oil appreciated for its quality.

Mechanical pressing: Extraction of edible oil using mechanical pressing is also recognized as a solvent-free alternative. Mechanical pressing process in the common practice consists of two stages, preparation and extraction. The preparation phase consists of cleaning, breaking, grinding and cooking, to make the material in optimum condition before being pressed (Fils, 2000). Cooking process is usually done at 90-115°C, then the extraction is done by screw press that can produce up to 71-82% oil recovery (Gunstone, 2004). This method is generally combined with solvent extraction to extract the remaining oil content in the meal (Lawson, 1995). Full-pressed method is rarely done in large-scaled industries but more popularly carried out in small industries (Fils, 2000). In comparison with aqueous extraction, mechanical pressing can be used more flexibly in these materials and capable of providing a higher yield. In small scale industries it can yield almost 71-97% oil/fat depending on the materials and expeller used (Gunstone, 2004). However, it can only be done on materials with high fat/oil content (Hamm and Hamilton, 2000).

Lately, the extraction of oil using a full-press, especially with the cold-pressed method is re-blooming. The fundamental difference with the general method is it does not use heat at all (CAC, 2001) apart from the heat generated due to friction during pressing. This method is preferred because it's a simpler process though it causes the resulting of slight yield, yet has very high quality and acquires premium price, mainly on the health-food market (Fils, 2000). Since this method is widely used on a small scale, yield becomes an important issue, even if the oil produced can be sold at high prices. On this scale, other than using a screw press, the use of hydraulic presses is also widely applied (Fils, 2000).

DEVELOPMENT IN AQUEOUS AND COLD PRESSING EXTRACTION

Enzymatic assisted: As mentioned above, the insufficient yield is the main problem facing solvent-free edible oil extraction. In some previous studies, the increase in extraction yield was done using enzymatic treatment as practiced by Sharma *et al.* (2001) and Najaifan *et al.* (2009). The list of several researches that has been carried out is shown at Table 1. The selection of a suitable enzyme is an important factor since every ingredient has a specific cell wall structure (Chen and Diosady, 2003). According to Ranalli *et al.* (2003) these enzymes, mainly pectolytic, cellulolytic, and hemicellulolytic species are applied in order to recover oil which is enclosed in the cell by breaking the cell wall. In virgin olive oil extraction, these enzymes were added to replace the endogenous enzymes that are deactivated during crushing and extraction process (Ranalli *et al*., 1998).

Ranalli *et al.* (1999) reported that the use of enzymes in the extraction of virgin olive oil increased the yield by 1% w/w (olive fruits basis); and in 2003, the following research indicated the increase in virgin olive oil yield rate of 12.5-14.6 kg/ton of processed olives (Ranalli *et al.*, 2003). Besides increasing yield, the use of enzymes also have positive influence in the increasing of its phenolic content (Faveri *et al*., 2008) of pinoresinol, orthodiphenol and non-orthodiphenol (Garcia *et al*., 2001). Ranalli *et al.* (2003) also reported that there is an increasing content of pleasant-volatile compounds (such as nonan-1-ol) and the amount of tocopherols. It also has been found that the use of enzymes increase the content of pleasant smells such as 1-penten-3-one, 1-penten-3-ol, trans-2-hexenal, 2-penten-1-ol, 1-hexanol, cis -3-hexen-1-ol, and trans-2-hexenol (Ranalli *et al.*, 1999).

The increase in oil yield was also reported in oil extraction from sesame seeds. When compared with controls (12.3% yield), treatment with enzymes was capable to produce yields as much as 16.5-24.8%. In addition, it also increased the content of tocopherols,

Table 1: The developed aqueous extraction condition of several oil

Raw material	Extraction method and enzymes type	Extraction procedure	Reference
Sesame seed	Aqueous extraction + commercial enzyme	Sample dispersed in 1:6 ratio of water, and then boiled. After cooled at room temperature, the pH was set at optimum condition of enzymes and then the enzymes was added. The mixture was incubated at 45ºC, 120 min at constant shaking 120 rpm. The solutions then centrifuged resulted three phases. Oily layer was collected by micropipette	(Latif and Anwar, 2010)
Olive	Aqueous Extraction + Industrial enzymes	Pre-treatment : The fruits is cleaned and removed the leaves then washed, milled by crusher to obtain a fine paste and kept frozen until use; Treatment : The temperature of the samples was adjusted to enzyme activity temperature in warm water bath, the certain doses enzymes were added in the beginning of the kneading; kneading at 80 rpm for 60 min. The paste was then centrifuged at 4500 g, 20 min. The separation of oil was carried out by heated the solution to dissolve the emulsion and then mixed with hexane	(Najaifan *et al*., 2009)
Sunflower seed	Aqueous extraction + commercial enzymes	The seed was ground, and then mixed with distilled water (1:6 w/v ratios). The mixtures then boiled and cooled down to room temperature. The enzymes was added after the pH of the mixtures was adjusted into optimum level. Incubation was carried out at 45ºC, 120 rpm for 2 h. The paste then centrifuged at 7000 rpm, 30ºC for 15 min. The oil at upper layer then collected.	(Latif and Anwar, 2009a)
Dry and wet milled corn germ	Aqueous extraction + commercial enzymes	Scheme 1 (cellulose + buffer) Corn germ was added by buffer than grinded by homogenizer. The enzyme was added and incubated for 4 h, 160 rpm at 50ºC, continued at 65ºC for another 16 h. After the mixture was cooled down, the mixture was centrifuged at 4000 rpm for 10 min. the upper layer was collected. The additional oil was gotten by centrifuging at 13.200 rpm for 10 min after white emulsion was removed Scheme 2 (cellulase and protease +buffer) Same with scheme 1, in addition after incubation at 50ºC, the mixture was added by potassium phosphate dibasic and then added by protease enzymes. The mixture continued to incubate at 50ºC for 2 h before continued to next incubation. Scheme 3 (cellulase and protease + no buffer) Same with scheme 1, in addition it's not use buffer but distilled water as well. And then after incubation at 50ºC, the mixture was added by KOH to adjust pH and then added by protease enzymes. The mixture continued to incubate at 50ºC for 2 h before continued to next incubation	(Moreau *et al*., 2009)
Chilean Hazelnut	Aqueous extraction + commercial enzymes	The seed was ground and transferred into reactor with water and a combination of enzymes then mixed by magnetic agitation. The mixtures then boiling to inactivate the enzymes and then centrifuged at 12.300 × g for 20 min at room temperature to separate the oil	(Santamaria *et al*., 2003)
Olive	Aqueous extraction + commercial enzymes	The olives was crushed by hammer mill then added by enzymes formulation (1:4, v/v enzyme : lukewarm water). The malaxation was carried out for 1 hour at 30ºC, and then the result was diluted to tap water for subsequent extraction and centrifuged at 4000 rpm. The oily solution was then separated into oil and water by vertical automated discharge centrifuge.	(Ranalli *et al*., 2003)
Coconut	Aqueous extraction + commercial enzymes	Coconut meat was ground with water. After that, the temperature was slowly increased to 50ºC and adjusted the pH to 4.5. The enzyme was added and incubated at 50-55ºC for 5 h with gentle agitation and continued at 50ºC without agitation for 15 h. The oil was separated by centrifuging at 9000 × g for 25 min	(Chen, 2003)
Peanut	Aqueous extraction + commercial enzymes and purified papain, chymotrypsin, and trypsin	The dehusked seed were ground by using high speed mixing blender. The paste was then dispersed in 1:2 ratio of distilled water followed by stirred gently using magnetic stirrer. The enzymes was then added and followed by pH adjustment. The incubation took overnight at 40ºC. the mixtures then centrifuged to separate the oil at 18.000 × g for 20 min. The oil then collected by Pasteur pipette	(Sharma *et al*., 2002)
Rice bran	Aqueous extraction + commercial enzymes	Rice bran was suspended in buffer then heated at 90ºC for 15 min to inactivate its enzymes. After cooled and adjusted to enzymes optimum temperature, the mixtures then placed to water-bath and stirred at 1000 rpm. Enzyme was added and incubated for 1-4 h. separation was carried out at 16.800 × g (10000 rpm) for 30 min at 20ºC	(Hanmoungjai *et al*., 2002)

Table 1: Continued

Rice bran	Aqueous extraction + commercial enzymes	Rice bran was dispersed in distilled water then stirred on a magnetic stirrer at 20 rpm for 30 min. the enzymes was added and the pH of the slurry was adjusted to the desired value, then the mixture was incubated at 65ºC with constant shaking (80 rpm) for 18 h. The solutions then centrifuged at 10,000 × g	(Sharma *et al*., 2001)
Olive	Aqueous extraction + commercial enzymes	The olive was crushed using hammer mill. The enzyme was added into paste before malaxation process. Malaxation was carried out at 14 rpm agitation; 30ºC for 1 h. first separation was done by using centrifugal decanter at 3500 rpm. Then oily must was centrifuge again by vertical centrifuge at 6500 rpm	(Garcia *et al*., 2001)

resulting in a higher total tocopherol content and similar different fatty acid composition with oil produced by solvent extraction and normal aqueous extraction (Latif and Anwar, 2010). Latif and Anwar (2009a) also studied the effect of enzymes on oil extraction from sunflower seed, which produces a much higher yield (26.6-39.7%) instead of 18.3% in normal aqueous extraction, close to the results of solvent extraction (45.5%). The increase in tocopherol content also occurred here, where the content of α and γ-tocopherol reached 516-582 and 259-268 mg/kg, respectively.

The application of enzymes in the beans products had previously reported by Sharma *et al.* (2002). Using commercial enzymes this process was capable to generate 100% higher recovery when compared to the absence of it, while papain, chymotripsin and trypsin enzymes were able to recover oil yields as much as 76, 61 and 67% respectively. Similar results were also shown by Hanmoungjai *et al.* (2002) with the use of aqueous enzymatic extraction of rice bran. The method could produce yields (what yield) up to 75%, followed by a 56% yield of protein extraction. Sharma *et al.* (2001) also reported that the highest oil recovery is obtained at 18 hours incubation and that mixing is important in this method. It was shown by the results of extraction that yielded as much as 76, 78, 67 and 60% at 50, 80, 100 and 200 rpm shaking using enzymes-assisted method compared to only 13, 14, 8 and 6% in the control treatment.

Not only performed on aqueous extraction, the use of enzymes is also done in cold pressing. Table 2 shows several cold pressing method assisted with enzymatic pre-treatment. The enzymatic pre-treatment using cold-pressing method did increase the yield of oil extracted. Latif and Anwar (2009b) reported that the yield of hemp oil extraction by this method raised 6-23%, which was 28.4-32.8% of oil extract compared to control (26.7%). Similar results were also reported by Soto *et al*. (2007) which achieved 76-87% oil recovery for borage oil extraction by single pressing (39.2 MPa) and up to 94.4% by dual pressing using enzymatic pre-treatment. 45ºC, 20% moisture and 9 h incubation found to be the optimum condition when compared to 66-85% and up to 89% at control treatment. For rose hip seed oil extraction, enzymatic pre-treatment resulted in the increase of yield, up to 36% compared to 47% oil yield for control (Concha *et al*., 2004).

Besides yield increase, Soto *et al*. (2008) had also reported that using enzyme-assisted cold-pressed method for borage, resulted in the increase of solids and phenolic compound recuperation as well as improve the antioxidant activity (as DPPH scavenging) compared to non enzyme-assisted cold-pressed method. The increase of tocopherols content has also been reported by Latif and Anwar (2009b) whom found the increase of tocopherols content at as much as 5-14%, and also the increase of other bioactive compounds as well.

Interesting results were reported by Sengupta and Bhattacharyya (1996), whom mentioned that in addition to producing solvent-free meals, meals resulting from oil extraction processes of mustard and rice bran with enzyme-assisted method had a higher protein and low ash content. This condition allows the meal to be a source of livestock feed. The same thing was reported by Chen and Diosady (2003) i.e., in addition to producing high quality coconut oil, the by-product produced by the process also has potential to be utilized. Ranalli *et al.* (2003) also mentioned that the enzyme preparation for olive oil extraction produced more environmentally friendly liquid waste, which reduced the potential of pollution up to 30%. Later research also found that the method did decrease the amount of solid particles and oil droplet at effluent which was equivalent to wastewater reduction by 30-35% (according to suspended solid content) (Ranalli *et al*., 2004). These results show that the enzymes-assisted method is one of environmentally friendly alternative technology that can be applied (Latif and Anwar, 2009a) because in addition to producing a high oil recovery, it also avoids the use of harmful solvents as well as its by-product (Concha *et al.*, 2004; Sharma *et al.*, 2002).

Ultrasound aided: The use of enzymes in oil extraction is not the only option that can be applied. Another method that has had attention is the use of ultrasound as an assist. Ultrasound use in olive oil aqueous extraction method was previously reported by Jimenez *et al.* (2007). In this method, the malaxation process was performed using ultrasound devices, which perform with indirect and direct sonication method at 25 and 24 kHz, 30ºC for 30 min, respectively. This method did increase the oil

Table 2: Several cold-pressed methods assisted with enzymatic pre-treatment

Raw material	Enzymes used	Extraction procedure	Reference
Rose hip seed	Commercial enzymes • Mainly cellulase and hemicellulase • Mainly betaglucanase, cellulase, and hemicellulase • mainly pectinase, cellulase, and hemicellulase	The dehulled seed was cleaned and ground. Then the ground seed mixed with water then heated into enzymes optimum condition. The enzyme was added and the mixtures then incubated. After that, the mixtures then dried and cold pressed using hydraulic presser.	(Concha *et al*., 2004)
Grape seed	Commercial enzymes	The incubation was carried out at 45ºC, 50% moisture for 9 h	(Tobar *et al*., 2005)
Borage seed	Commercial enzymes • Mainly pectinase, cellulose and hemicellulase • Mainly cellulose and hemicellulase	The seed was cleaned and then crushed using screw mill. The ground seed then conditioned at 100ºC for 20 min. Then the mixtures was added by water and enzymes solution then incubated. Sample then dried using vacuum dryer. Pressing was carried out by hydraulic press at 49 MPa for 20 min	(Soto *et al*., 2007)
Borage Seed	Commercial enzymes	Crushed seeds were thermally treated in boiling water. The incubation was done at 45ºC for 9 h. after the sample was dried, pressing was carried out by hydraulic presses at 49 MPa for 20 min	(Soto *et al*., 2008)
Hemp seed	Commercial enzymes • Protease • multi-enzyme complex containing a wide range of carbohydrases, including arabanase, cellulase, β-glucanase, hemicellulase, and xylanase • mainly cellulase, xylanase, phytase, α-amylase, pectinase • mainly xylanase, β-glucanase, cellulase and hemicellulase • mainly α-amylase, β-glucanase, cellulose complex, hemicellulase complex, protease and xylanase	After cleaned, the seeds were ground and sieved at 80-mesh sieve. After adjusted to enzyme optimum condition, the mixture was then incubated at 40ºC for 6 h. Drying process was carried out until it had 3-4% moisture content. Dried sample was pressed by hydraulic presser at 29.4-49.0 MPa for 20 min	(Latif and Anwar, 2009b)

Table 3: Several vegetable-oil extractions carried out by supercritical CO_2

Raw Material	Extraction Condition	Reference
Sesame seed	Temperature : 313 to 333 K Pressures : 19 to 25 MPa Flow rate : 0.8 cm^3/min	(Corsoa *et al*., 2010)
Grape seed	Pretreatment : Enzymatic Extraction condition : Temperature : constant 313.15 K Pressures : 160, 180 and 200 bar Flow rate : 1.7 x 10^{-4} kg/s	(Passosa *et al*., 2009)
Canola seed	Temperature : 40, 50 and 60 ºC Pressures : 20, 22.5 and 25 MPa Flow rate : 0.8 cm^3/min	(Pederssetti *et al*., 2011)
Wheat germ	Temperature : 40ºC Pressures : 200, 250 and 300 bar	(Piras *et al*., 2009)
Jojoba seed	Temperature : 343 and 363 K Pressures : 25, 35 and 45 MPa Flow rate : 3.33, 6.67, 13.33 × 10^{-8} m^3/min	(Salgın, 2007)
Hazelnut	Temperature : 308, 313, 318, 321 K Pressures : 18, 20, 22, 23.4 MPa Flow rate : 4.42, 5.42, 6.42, 7.10 ms^{-1}	(Bernardo-Gil *et al*., 2002)
Walnut	Temperature : 308, 313 and 318 K Pressures : 18, 20, 22 Mpa	(Oliveira *et al*., 2002)

extractability significantly and did not alter the fatty acid composition of the oil that was produced. Meanwhile, with the cold-press method, ultrasound can also be used as a pre-treatment instead of using enzymes or heat, as performed by Azadmard-Damirchi *et al.* (2010), whom used the pre-treatment condition of 2450 MHz for 2-4 min. The obtained result was an increase in yield of rapeseed oil up to 18% using 2 min and 25% for 4 min pre-treatment.

Supercritical fluid extraction: Instead of aqueous extraction and cold-pressing method, the new term of solvent extraction also provide "green" technology to be applied. This method, namely supercritical fluids (SFE) usually use CO_2 as its solvent, which was promoted as environmentally friendly compared to others. CO_2 is utilized due to its unique solvating power; which is controllable and regulated by relatively small changes in temperature and pressure when above its critical point

(304.15 K and 7.38 MPa) (Brennecke, 1997). Some research about it has been conducted with samples of sesame seed (Corsoa *et al.*, 2010), grape seed (Passosa *et al*., 2009), wheat germ (Piras *et al*., 2009) and others, details of which are shown at Table 3.

Based on previous research, the use of this method on high oil content samples such as walnut, were capable of producing the oil recovery up to 95% at its maximum extraction time (390-minute), but the 150-minute process (85%) is reported as the most efficient condition due to its shorter time and the less use of CO_2 (Oliveira *et al*., 2002). It's also reported that this method resulted in a higher content of tocopherol and clearer oil compared to the oil from hexane extraction. Bernardo-Gil *et al.* (2002) also reported the use of this method on hazelnut, which resulted in higher total tocopherol content (458.7 μg/g oil) compared to 382.2 μg/g oil acquired from n-hexane extraction. It is also mentioned that there was a little difference in fatty acid composition obtained from SFE and n-hexane method. Oil extracted from SFE had lower content of PUFA, higher content of MUFA and so on higher ratio of unsaturated to saturated fatty acid value.

A study of seeds samples was carried out by Salgin (2007) on jojoba seed, which concluded that the use of this method was capable of producing yields up to 44% (w/w). This study also showed that the addition of ethanol in the process of SFE CO_2 extraction could improve the process performance and generate up to 62% yield. Other studies on grape seed carried out by Passosa *et al.* (2009) was able to produce as much as 11.5% yield. The interesting part in this study is the use of enzymatic pre-treatment in the method; it was able to increase the extraction's performance by 43.5% resulted in 16.5% yield.

Recent studies conducted with sesame oil show that this method could produce yield up to 35%, notably high when compared to hexane extraction of 52.6% and the use of the propane in the same method that produced 33.5% yield. Although producing a lower yield, the extraction using propane can be done in a much shorter time (40-70 minute) when compared with using CO_2 as a solvent that spent 510-1380 minute, and the pressure utilized was also lower (Corsoa *et al.*, 2010). The use of this method in canola samples (37% oil) showed slight differences; the use of propane as solvent could produce a higher yield of up to 23.83% compared to only up to 19:49% by using CO_2. However, the extraction using propane in these samples also required the lower value of pressure and time (Pederssetti *et al*., 2011). Although in these experiments, the use of CO_2 is not able to surpass the use solvents or other materials such as hexane and propane, the use of a safer and more environmental friendly solvent can be a good reason for these methods to be further developed. In addition, the results of chemical-free by-products, makes it more flexible to be developed into other potential materials through the methods described previously.

Edible oil refining technology: The application of rendering and cold pressing methods indeed produce high quality oil and a premium value on the market. However, with a high content of non-triglycerides in it, these types of oil is unsuitable to be applied in the use of which requires a neutral oil in terms such as colour, flavour, etc. For example, the flavour produced by the virgin olive oil may be preferred as a salad dressing or cooking oil, but on the other hand, it would be very inconvenient for a large industry that wants products, so they're uniform and unaffected by variations in the type and quality of oil used. The presence of the colour pigments in oil that is processed in such as the manner, which varies greatly in each batch, also makes it difficult to make products that have a certain colour appearance if the oil is used directly. Therefore, it is still necessary for the oil refining process as a process carried further in certain cases. E.g. if the extraction results obtained are not in accordance with expectations, it is insufficient to meet the market requirements, which is needed to improve the quality or processing of information to be used as it should. And in special cases, purification is quite necessary, as in certain types of oils or fats containing compounds that are hazardous to health if consumed by humans.

In general, edible oil refining can be done either chemically or physically. Degumming, chemical neutralization followed by physical refining of bleaching and deodorization, might be the most conventional process that is widely used. This process, as explained earlier, is objected to converting crude oil or fat into a more suitable form for the subsequent use. Typically, it will produce oils that have minimum colour and flavour because the minor compound, which is not desirable, has been removed during the process (Gunstone, 2004). According to Greyt and Kellens (2000), degumming process was intended to remove the phosphatides and mucilaginous material from crude oil by means of washing with water, dilute acid or sometimes dilute NaOH. Gunstone (2004) also mentioned, that phospholipids are powerful emulsifying agents, and that if not removed, will increase the refining losses and decrease the oil oxidative stability due to its ability to carry pro-oxidants associated metals. Neutralization process utilises alkaline compounds to produce soapstock so that it can be separated from the oil body. Soapstock contains free acid in the form of sodium salt, which is mixed with triacylglycerols and phospholipids. This by-product will then be acidified again to get the fatty acids that can be used for the soap manufacture or animal feed additives.

The next stage, namely bleaching is a process that is aimed to eliminate colour substances that are not desired in the oil. This process is done by mixing the oil with a small amount of adsorbent or can be done chemically (Ketaren, 1986). However, the process in addition to using the adsorbent, i.e. hydro-bleaching or chemical bleaching is not utilized on edible oil refining (Greyt and

Kellens, 2000). The final process, which is deodorization, is designed to produce oil with a bland flavour, odour and good shelf life. This process usually undergoes high temperatures between 170-250ºC under reduced pressure to volatilize the oxidation products responsible for oil off-flavours (Gunstone, 2004).

Physical refining as eco-friendly alternative: In the context of environmentally friendly technology, physical refining is an appropriate solution due to its ability, in addition to reducing the risk of environmental damage, to produce higher oil yields. Although in this case, physical purification is delicate to be applied to all types of crude oil (Greyt and Kellens, 2000). Bleaching process, in term of adsorptive refining, is one of the methods that gets a lot of attention, not only because of its flexibility both in the process as well as the source, but also reported is its capability of substituting other purification processes. As reported previously by Proctor and Harris (1996), the use of adsorptive agent, in this case, the soy hull carbon as refining agent, can lower the levels of lutein, Free Fatty Acid (FFA), Peroxide Value (PV) and phospholipids phosphorus content in soy oil. It is also supported by the research of Sabah and Çelik (2005) that reported the use of sepiolite as the adsorptive agent, in addition to producing a pale color, was also able to reduce levels of FFA, PV, anisidine value, and phosphorus content in oil. Furthermore, it also reported that the performance of the process increased along with the increase of adsorbent concentration.

As mentioned earlier, oxidation products are usually removed from oil when the alkali neutralization and deodorization process is carried out. Deodorization process uses a high temperature steam (>220ºC) which raises the issue of degradation of vitamins and the formation of trans-isomers and polymers (Gumuskesen and Cakaloz, 1992; Gunstone, 2004; Maza *et al*., 1992). Adsorptive refining, although more effectively done at higher temperatures (Zhu *et al*., 1994), can also be done at a lower temperature. This is very useful especially in oil products that are sensitive to heat treatment such as fish oil (Francis, 1999). As practiced by Huang and Sathivel (2010) who performed this process only at a temperature of 22oC in salmon oil samples. The process, in addition to producing better colour appearance; is also capable to reduce the level of FFA in oil.

In addition to previously mentioned advantages, this process also offers an attractive flexibility. Many choices of adsorbent types can be used make this process easy to apply for more specific results. Besides a wide choice between synthetic and natural adsorbents, the utilization of by-products converted into an adsorbent allows the application process for a zero-waste clean technology. Adsorbent, including chitosan, activated carbon, activated clay, sepiolite, soy hull carbon, rice hull ash, attapulgite and other clays mineral (Boki *et al*., 1992; Huang *et al*., 2007; Huang and Sathivel, 2010; Proctor and Harris, 1996; Proctor and Palaniappan, 1990; Sabah and Çelik, 2005; Sathivel and Prinyawiwatkul, 2004) are an option that can be used in addition to synthetic adsorbents, including Magnesol XL, alumina (aluminum oxide), magnesium silicate, silica (silicon dioxide) and others (Boki *et al*., 1994; Farag and El-Anany, 2006). Another interesting study is that this method can remove the harmful content of pigments such as gossypol in cottonseed oil than the previously done chemical alternative, as reported by Kuk and Tetlow (2005) and Kamga *et al.* (2000) using alumina, silica, magnesium silicate and bentonite as the adsorbent agent.

Among others, the terms membrane filtration and modified deodorization can also be used. The study carried out by Bottino *et al.* (2004) on extra virgin olive oil, Koris and Vatai (2002) in sunflower and soybean oil, Lin *et al.* (1997), Snape and Nakajima (1996) and Subramanian *et al.* (1998) mentioned that membrane filtration is able to reduce wax, phospholipids, suspended particles, and even the trace amounts of heavy metals like copper, iron and manganese in the oil. Whereas modified deodorization uses other medium i.e. nitrogen bubbles as a stripping medium to allow the use of lower temperature, instead of steam. As reported by Tsiadi *et al.* (2001), the use of nitrogen bubbles on sunflower oil deodorization was possible to remove some volatiles and odoriferous compound under 150ºC condition, although higher molecular compound such as FFA could only be done at temperature of not less than 180ºC.

CONCLUSION AND RECOMMENDATION

The development of environmentally friendly process has its definite difficulties and challenges. The increase in yield that can be achieved by the methods described previously is certainly a very suitable solution applied to small industries. However, the use of these methods on large industries will be a dilemma, where the quantity produced is a far comparison to the common method of solvent extraction. The higher cost, especially in enzyme procurement and ultrasound infrastructure pose a significant problem. Even so, as the growing trend of healthy products in which less-processed product such as virgin oil are well appreciated and rewarded with premium prices, this scenario is without doubt an opportunity that cannot be ignored. The increasing public awareness of the environment has also helped to change the paradigm. Buyers these days do not mind paying more for organic and chemical free products. Furthermore, the possibility of clean production can also be developed due to the possibility to reuse the by-products generated.

The ease of application is clearly the advantage of aqueous extraction; moreover, its performance can be

improved with either of the use of enzymes or ultrasound assistance. Cold extraction process promises a consistent means to produce high enough yield. Supercritical fluid extraction provides a technique with high extraction rates. Meanwhile, the purification technique, flexibility and ease of application are the advantages of adsorptive refining, whereas more specific purpose can be obtained by membrane filtration. With these advantages, surely there is no reason to not be able to produce high quality edible oil with environmentally friendly methods; all the more, because it is much appreciated with a high price in the market.

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