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Supercritical carbon dioxide (SC-CO_2) as a clean technology for palm kernel oil extraction

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Abstract

Efforts towards application of Supercritical Carbon Dioxide (SC-CO_2) extraction in Malaysia are still at its infancy stage. More research has actively on-going to explore its potential performance on a bigger scale (industrial scale) so that it will provide a better alternative method of extraction compare to the present practice using organic solvent extraction. SC-CO_2 has been proven on laboratory and pilot-scale as an effective extraction technique for large types of bio-materials such as herbs, natural plant materials like legumes, nuts and palm oil and others. Thus, this paper is aimed to highlights the application of SC-CO_2 in extraction of oil from a single palm kernel and also to demonstrate its application in estimating or inventoried the amount of CO_2 consumed and release to the atmosphere in relation to green house effect in compliance to Kyoto Protocol.

Keywords: By-product, Solvent extraction, Kyoto protocol, Supercritical Carbon Dioxide, Palm Kernel Oil

Introduction

Currently, vegetable oils and fats such as peanut, soybean, sunflower and rapeseed, palm oil has secured a substantial share of the world market. Malaysia accounts for 51 % of world palm oil production and 62 % of world exports, and therefore also for 8 % and 22 % of the world's total production and exports of edible vegetable oils and fats. Similarly, production of palm kernel oil (PKO), a by product obtained from processing the fruits of the oil palm, has also been increasing. Production of PKO in the year 2000 totaled 2.68 million tones and accounted for 2.3 % of the total production of the major oils and fats (Mohd Nasir 2001). Trade of the palm kernel on the other hand in the year 2000 was 1205 thousand tones. As the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing need for oils and fats.

Palm kernel oil, is the major lauric oils that are great demand for industrial and specific edible and non-edible applications. The common application in edible uses include margarine, compound cooking fats, artificial cream fillings, coffee whiteners and confectionery applications. But, for the non-food uses are commonly used for the manufacture of personnel care products, soaps and detergent.

Palm kernel oils consisted glycerides and non-glyceride components to be removed or reduced to acceptable levels in order to convert it into an edible form. The non glycerides are of two broad types: oil soluble and oil insoluble. (Mohd Suria 2001).

Conventional Method of Extraction

Figure 1 illustrates the current conventional method of palm kernel oil extraction to yield crude palm kernel oil which involves various methods such as screw press, solvent extraction (using organic solvent) and screw press followed by solvent extraction**.** These methods normally remove the insoluble oil impurities such as fruit fibers, nut shells and free moisture. However the oil soluble non-glycerides which include free fatty acids, phospholipids, trace metals, carotenoids, tocopherols/tocotrienols, oxidation products and sterols, are much more difficult to remove and thus, the oil needs to undergo various stages of refining for example, chemical or physical refining to yield refined bleached and deodorized palm kernel oil (RBDPKO). The refining technique consists degumming, bleaching and deodorization. The refined oils may be further processed by fractionation, hydrogenation and for different food uses. Each of these technological processes affects the nature of the oils.

Environmental Concerns

Due to an increased awareness on environmental safety, traditional solvents have been thoroughly scrutinized. Moreover, this traditional method has created other disadvantages such as pollution problem, increase cost of energy, and intensive separation

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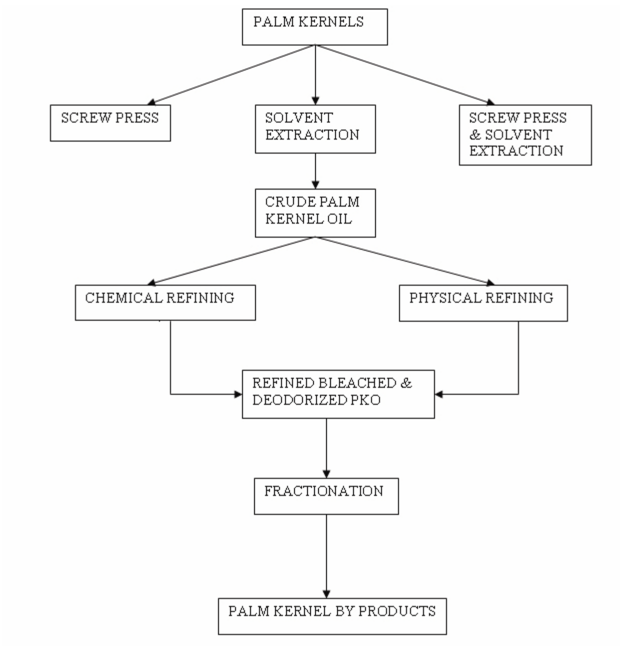

Figure 1: Flow chart of conventional method of Palm Kernel Oil Extraction

techniques as well as less lucrative that motivate companies to practice a cleaner production method. The importance of Cleaner Technology or in the other form that it may take, Pollution Prevention or Green Productivity, on a global scale can already be seen from the formation of the United Nation Environment Programmed (UNEP), Cleaner Production initiative and the mushrooming of pollution prevention centers in the USA backed by strong federal government support. According to Chow Kok Kee (2002), the Clean Development Mechanism (CDM) as introduced in Article 12 of the KYOTO Protocol aimed in the reduction of Green House Gas (i.e CO_2) emissions which contribute to sustainable development. The application of cleaner production will in the long term, safeguard our natural resources and help to secure a competitive advantage for Malaysian industries (Marina 1999).

Environmental legislation enforced by most countries, like in Malaysia, is directed essentially towards pollution abatement through the implementation of waste treatment and disposal schemes with the aim of conforming to stipulate discharge or emission standards. Although such practice, referred to as end-of-pipe treatment, has contributed significantly to environmental protection, it is not an ideal approach in environmental management. In fact, such approach has, in certain cases, proved grossly inadequate and problematical. It has resulted in the transfer of pollutants, particularly those categorized as hazardous, from one medium to another (Teoh 1999).

Cleaner technology is a relatively new concept and approach in pollution control. This strategy, which entails reduction, recycling, or even elimination of waste sources through prevention and recycling of wastes generated, is undoubtedly more environmentally sound and acceptable.

The Supercritical Carbon Dioxide Extraction as a Clean Technology

In the past decade or so, the underlying principles and process applications of supercritical fluids (SCF) extraction as a clean technology, have been investigated by numerous industrial and academic research and development laboratories. This interest was due to the possibility of separation of multi – component mixtures using environmental friendly SCF solvents (Galia et al. 2002). Today, Supercritical Fluids (SCF) is increasingly replacing the organic solvents that are used in industrial purification and recrystallization operations due to regulatory and environmental pressures on hydrocarbon and ozone-depleting emissions (R.S. Mohamed et al, 2000). SC-CO_2-based processes for example, have helped to eliminate the use of hexane and methylene chloride as solvents. With scrutiny of solvent residues in pharmaceuticals, medical products, and neutraceuticals, and with stricter regulations on volatile organic compounds (VOC) emissions, the use of SC-CO_2 is rapidly proliferating in all industrial sectors.

The Supercritical Carbon Dioxide Extraction Method

Figure 2 illustrates the flowchart for extraction of palm kernel oil from a single palm kernel using SC-CO_2 technique. The apparatus used for contacting the single palm kernel with supercritical carbon dioxide is shown in Figure 2. The various components of SC-CO_2 extraction equipment consists of a carbon dioxide cylinder (MOX, Penang) with 99.99 % purity of CO_2, a chiller (Yih Der Bl – 730) to liquefy the CO_2 gas, high pressure 100 DX syringe pump with maximum operating pressure of 689.5 bar (Isco, Inc.,Lincoln, NE. U.S.A), an SFX 220 extractor with size 22.7 cm by 21.2 cm by 24.4 cm (Isco, Inc., Lincoln, NE. U.S.A.), equipped with a 2.5 ml extraction vessels, a heated capillary restrictor 50 µm with maximum operating temperature of 150 ^{o}C use to minimize analyte deposition, and a 30 ml vial to collect the analyte. As can be anticipated from Figure 2, the SC-CO_2 technique of extraction involves less unit operations and is a fast process as opposed to the current conventional method. By using SC-CO_2 method, extraction, fractionation and separation of palm kernel oil in a single palm kernel could be done simultaneously.

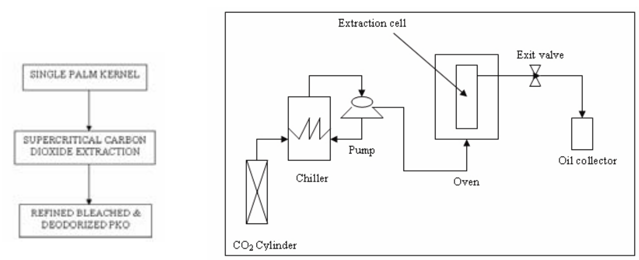

Figure 2: Supercritical Carbon Dioxide (SC-CO_2) Extraction Apparatus

The advantages of SC-CO_2 as a solvent as opposed to other organic solvents

The advantages of using carbon dioxide (CO_2) as a solvent are crucially attributed to the fact that, besides having a convenient critical temperature and pressure (31.1 ^{o}C & 72.8 bar), it also demonstrates a chemical stability, non-flammability, stability in radioactive applications and toxicity and therefore it can replace hazardous organic solvents and thus provide a valuable pollution prevention tool (Hugh and Krukonis 1986). Further, it is available in large amounts under favorable conditions and largely independent of the petrochemical industry; large reserves in liquid form are technically available.

Besides having low viscosities, high miscibility, and high diffusivities, CO_2 also provide potential for faster reactions, particularly for diffusion–controlled reactions or processes involving gaseous reagents such as hydrogen, oxygen, or carbon monoxide. Also, there is ***no residual solvents*** in the final extracted material or residue since CO_2 is gaseous at room temperature and pressure and can be easily separated from analytes by decompression therefore the recovery percentage is high (Dean 1993).

What is more, the color of extracted product is lighter and characteristics of the finished products are generally superior to the conventional methods as it is free from inorganic salts, heavy metals and free of micro bacterial life. Moreover, CO_2 cannot be oxidized further, and thus could be an ideal solvent for carrying out oxidation reactions (Weatherly 1994). Above all, CO_2 has low energy utilization due to low heat of vaporization at the critical point as can be seen in Table 1.

Table 1: Heat of vaporization of carbon dioxide

Temperature (K)	Saturation Pressure (kNm^{-3})	Heat of vaporization ($kJkg^{-1}$)
255	2107	279
277	3910	221
289	5156	178
294	5886	148
300	6676	104
304	7365	0

With these special properties of CO_2 as an environmental friendly solvent has lead to the development of SC-CO_2 processing particularly in the oil and fat industry. Examples of these are deacidification of olive oil (Brunetti et al. 1989), extraction and chatacterization of cottonseed oil (G.R.List et al. 1984), refining of palm oil (Ooi et al. 1996) and fractionation of butter oil (Majewski et al. 1991). Additionally, extraction of oil from, sunflower and rapeseed with SC-CO_2 has been described by Stahl et al. (1980), Bulley et al. (1984), Friedrich et al. (1984) and Eggers et al. (1985).

Table 2: CO_2 Inventory

Temp (^oC)	Pressure (MPa)	CO_2 pump Capacity (ml)	Volume of CO_2 consumed (ml)	Volume of CO_2 Released to the atmosphere (ml)
40	27.6	103	64.8	38.2
	34.5	103	67.2	35.8
	41.4	103	68.4	34.6
	48.3	103	75.3	27.7
50	27.6	103	60.6	42.4
	34.5	103	62.4	40.6
	41.4	103	66.9	36.1
	48.3	103	73.8	29.2
60	27.6	103	59.1	43.9
	34.5	103	60.6	42.4
	41.4	103	65.7	37.3
	48.3	103	68.4	34.6
70	27.6	103	70.2	32.8
	34.5	103	63.6	39.4
	41.4	103	68.1	34.9
	48.3	103	65.7	37.3

Inventory of CO_2 Released

Through SC-CO_2 Extraction of palm kernel oil from a single palm kernel, it is possible to conduct an inventory of CO_2 release to the atmosphere in order to comply with KYOTO Protocol. Table 2 shows the amount of CO_2 consumed and released as a function of temperature and pressure during the SC-CO_2 extraction of palm kernel oil in a single palm kernel. From Table 2, it was found that the amount of CO_2 consumed increased with temperature and pressure. However the amount of CO_2 released to the atmosphere decrease with an increased in temperature and pressure. Thus, it is evidence that with SC-CO_2 extraction of palm kernel oil from a single palm kernel could provide a tool for a better estimation of CO_2 inventory.

Conclusion

In conclusion, application of SC-CO_2 is cleaner production /technologies for extraction of palm kernel oil in a single palm kernel. This techniques has several advantages in terms of time saving, energy saving, pollution free, fast and safe. In compliance to KYOTO Protocol this technique has successfully demonstrated an accurate estimate or inventoried CO_2 consumed and released to the atmosphere. Hence, this method contributes greatly to an approach of solving world global warming.

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