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Optimisation of Oil Extraction Process from Australian Native Beauty Leaf Seed (*Calophyllum inophyllum*)

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Abstract

In this study, the oil extraction process from Australian native beauty leaf seed has been optimised in terms of seed preparation and cracking, seed kernel treatment, moisture content and oil extraction methods. Two methods: mechanical oil extraction using an electric powered screw press and chemical oil extraction using n-hexane as an oil solvent have been applied to extract oil from the seed kernel. Both whole and grated kernels have been used for mechanical oil extraction process. The study indicated that treatment of seed kernel has a significant impact on oil yields for both techniques. It has been observed that kernels prepared to 15% moisture content provided the highest oil yields for both extraction methods. Mechanical extraction using the screw press could produce oil from the prepared kernels at a low cost. In addition, it has been obtained that oil yields by using grated kernels were relatively higher than the whole kernels. However, oil extraction by using this technique is ineffective due to relatively lower oil yields compared to chemical extraction. On the other hand, chemical extraction was found to be a very effective method for oil extraction because of its consistence performance and high oil yield, but cost of production was relatively higher due to high cost of solvent. The outcomes of this study are expected to serve as the basis on which industrial scale oil extraction can be made from beauty leaf seed.

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Keywords: Beauty leaf seed, 2nd generation biodiesel**,** Oil extraction process, Moisture content, Electric powered screw press

1. Introduction

The declining reserves of fossil fuels and the growing environmental concerns have stimulated scientists and industries to search for and evaluate alternative fuels for petrol and diesel engines [1-3].

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Furthermore, an urgent need to reduce dependence on petroleum fuels for better economy and environment is required [4]. Liquid bio-origin fuels are renewable fuels coming from biological raw material and have been proved to be good substitutes for oil in transportation and agriculture sector. In particular, biodiesel fuels are attracting thriving attention worldwide as a blending component or a direct replacement of diesel fuel in vehicle engines [1, 5]. Therefore, biodiesel is considered as one of the most promising alternative resources for diesel engines especially from non-edible oil feedstock [6, 7]. Biodiesel is biodegradable, environmental friendly, non-toxic, portable, readily available and eco-friendly fuel [8-10]. It (fatty acid methyl esters) is derived from vegetable oils as well as animal fats through the esterification and transesterification reactions of free fatty acids (FFAs) and triglycerides, respectively, that occur naturally in renewable biological sources [1, 11]. It can offer a lot of benefits, including reduction of greenhouse gas emissions, regional development and social structure especially to developing countries [12]. It is a good lubricant which is about 66% better than petrodiesel [13].

Edible vegetable oils are referred to as the 1st generation feedstock and non-edible or waste known as the 2nd generation feedstock. Although 1st generation biodiesel produced from edible oil has gained the attention, the edible oil based biodiesel faced the problem of 'food versus fuel' debate and these factors have negatively affected on biodiesel production from edible oils [14]. It has been seen that the price of biodiesel mainly depends on the cost of feedstocks which makes up 70-80% of the total biodiesel cost [15]. The selection of 2nd generation feedstock is due to the high costs of edible biofuel feedstocks for biodiesel production [15]. Therefore, the use of cost-effective 2nd generation feedstocks can be a way to improve the economy of biodiesel production and its commercial production at an industrial scale. However, due to the problems associated with food versus fuel, environmental and economic issues related to 1st generation, the 2nd generation feedstocks [15] is gaining popularity for biodiesel production.

Research is currently taking place on 2nd generation biodiesel which is aimed at addressing the 'food versus fuel' debate [16]. However, the current production of above mentioned feedstock does not come close to a value representative of replacing fossil fuel use. In a recent study, a large number of native species have been assessed for growth on degraded land in Australia which produces biodiesel at appreciable quantities [17]. Among them, beauty leaf (*Calophyllum inophyllum)* has been identified as the most suitable feedstock for future generation biodiesel feedstock. However, its potential as a source of 2nd generation biodiesel is yet to be assessed due to a lack of knowledge of the production process. This study aims to describe the optimisation of oil extraction process from beauty leaf seed in terms of seed preparation and cracking, seed kernel treatment, moisture control as well as oil extraction methods.

2. Seed Preparation

Preparation of seeds for oil extraction involves removal of outer layers fruits to expose kernels, and then drying the kernel to a desired moisture content [18]. About 25.5 kg of seeds were procured from Australian native plant suppliers. The seeds were separated from fruits and the fruits were cracked open manually. The separated seed kernels were sieved, cleaned and stored at room temperature. The seed kernels procured from various sources were dried at 65 to 70^0C for 3-4 days in the oven.

2.1. Kernel extraction

The first stage of preparation of seeds for oil extraction was removing the outer layers to expose the kernel. The seeds were cracked open in order to obtain kernels for further processing. The seed cracking process used two methods: stompers and mallets. For the stomper, a large number of seeds were placed on the ground and worked until a number had been cracked and then the kernels and the waste husk were removed. For the mallet, operators placed a handful of seeds on the table surface and cracked them individually, before removing the kernels and the waste husk as shown in Fig. 1.

Fig. 1. Beauty leaf seed cracking area

Approximately 9kg of usable kernels were obtained from the procured 25.5 kg of product. This translates to approximately 35% of the total procured mass being usable kernels. The seeds were cracked using mallets either individually or only several at a time whereas, the stomper was capable of cracking numerous seeds at a time. It was also observed that the rubber-headed mallets were preferred than wooden or steel-headed mallets, as they tended to rebound excessively. However, due to the variability is size of the seeds, the efficiency of the stomper was reduced as it only struck the largest seeds with each blow. Overall, kernel extraction was found to be a time-consuming and labour-intensive process. It has been estimated that each method was roughly equal in cracking rate, at approximately 2 to 3 kg of seeds were cracked per operator per hour. However, cracking process may be automatable to increase the cracking rate.

2.2. Kernel drying

The kernel or seed has to be prepared in such a way that it contains optimum moisture content for high oil yield. It has been observed that kernels with 15% moisture content provided the highest oil yields in both mechanical and solvent extraction methods [18]. The seeds have to be dried before oil extraction takes place. The drying process was conducted using a laboratory scale Clayson electric oven with temperature controller. Nine samples of kernels were placed in the aluminium foil trays and per tray contain 1 kg of kernels to ensure the product was spread adequately for uniform drying in an oven as shown in Fig. 2. Kernels were dried at 65^0C to 70^0C to determine the effect of mulching as well as temperature on drying rate.

Fig. 2. Kernel drying in the oven (left side: whole kernel and right side: grated kernel)

Fig. 3 Mechanical oil extraction through a screw press

The drying process was checked very carefully by weighing the trays several times in a day and the samples were also stirred to provide aeration for uniform drying. For drying rate comparison, the percentage dried was plotted against drying time for the samples. After reaching the desired dryness; the trays were immediately removed and stored in a refrigerated store room. The kernel samples were obtained with 10%, 15% and 20% moisture content which were used to investigate the effect of moisture content on bio-oil production.

3. Oil Extraction Techniques

Two methods have been used for extracting oil from prepared seed kernels. These are mechanical oil extraction suing an electric powered screw press and chemical oil extraction using n-hexane as a solvent. In both cases, experiments were conducted to find out optimised moisture content for high oil yield.

Fig. 4. Chemical oil extraction (lest side: oil yield in the trays and right side: conical flasks with oil content in the shaker machine

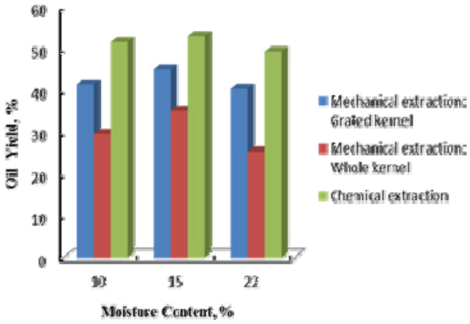

Fig. 5. Oil yield against absolute moisture content for both mechanical and chemically processed samples

3.1. Mechanical extraction

The technique for oil extraction by mechanical presses is the most conventional one among the other methods. In this method, either a manual ram press or an engine driven screw press was used. The mechanical oil extraction technique was conducted using a mini 40 screw press at Centre for Plant and Water science (CPWS) in Central Queensland University (CQU) as shown in Fig. 3. Properly dried and treated beauty leaf kernel samples were used to extract oil by this method. It was found to be very difficult to process kernel by using this screw press. Three samples of whole and three samples of grated kernels were used to perform the experiment. Seed kernel samples were ground using a blender machine. Operator was required constantly to attend and operate the machine. It has been observed that the rate of oil production was very slow, typically taking couple of hours to process just one sample. It could be noted that grated kernels provided higher oil yields than the whole kernels [19]. The screw press used in this experiment was not designed for beauty leaf seed, it was realised that using this press for oil extraction not only would be challenging but also would require a degree of experimentation to adjust pressure and speed. Therefore, some modification has been done to control proper operation during the experiment. For instance, glad wrap was used around the machine to capture any split material for the specific purpose of keeping mass control as precise as possible in order to give the most valid oil yield results. Therefore, the design of mechanical extractor is very important in conventional mechanical presses techniques since the oil yield is affected by the type of mechanical extractor is used. Mahanta and Shrivastava [20] reported that the mechanical presses are not efficient for extraction of oils because of the problems associated with non-edible seeds. The most consistently high oil yields were produced with 15% absolute moisture content as shown in Fig. 5. However, further improvement of beauty leaf oil extraction using the screw press is possible by optimising key design parameters of the machine including pressure, compression ratio, speed, and hot pressing.

3.2. Chemical or solvent extraction

Solvent extraction is the process in which constituent is removed from a solid by means of a liquid solvent. It is also called leaching. The chemical extraction using n-hexane method results in the highest oil yield which makes it the most common method. Three samples of grated kernels were used to perform the oil extraction process. For chemical oil extraction, dried seed kernel samples were ground using a blender and coffee grinder to obtain a fine consistency to maximise particle surface area. The ground kernels were put into conical flasks in which n-hexane were added at a ratio of 2:1 (ml hexane: grams kernel). This mixture was given an initial stir to ensure that all kernels were wetted with hexane. Conical flask openings were covered with aluminium foil and placed on the orbital mixture shaker machine for shaking and the samples were left to run at least 20 to 24 hours. Then the hexane/oil mixtures were collected, filtered and decant into aluminium foil containers for solvent evaporation and placed under the fume hood as shown in Fig. 4 for 20-24 hours. Ashwath [17] and Jahirul et al. [18] conducted the chemical oil extraction technique using n-hexane to extract oil from beauty leaf seeds (*Calophyllum inophyllum*). Hexane was again added to the conical flask of kernels, but at a ratio of 1:1 for the second extraction by applying the same procedure. In this way, up to fifth extraction was completed by following the similar procedure for recovery of the oil. When it was determined that the hexane had been fully evaporated the oil was transferred into containers for further analysis.

In terms of oil yield from the two extraction methods, solvent extraction was vastly more successfully. For the test sample extractions as shown in Fig. 5, the samples with 15% absolute moisture content produced the highest oil yields, averaging approximately 54% (with respect to input dry mass). The difference was only between samples with an absolute moisture content of between 10% and 15%. However, the major barrier for solvent extraction process is the cost of solvent.

4. Comparison of Oil Extraction Methods

The results from the mechanical and chemical extraction processes clearly indicate that the hexane technique is superior in terms of producing higher oil yields. It was also observed that solvent extraction is more repeatable, relative ease of preparation and no requirement for extensive training. However, seed preparation has a significant impact on oil yields especially for the screw press extraction method. Kernels prepared to 15% moisture content provided the highest oil yields for both extraction methods. Although the oil extraction technique using the mechanical screw press was obtained at a low cost but this is ineffective due to relatively lower oil yields. This process is relatively inexpensive after initial capital costs. Moreover, this process is time consuming and labour intensive. On the other side, the chemical oil extraction technique was found to be very effective because of high oil yield and for its consistence performance but the lack of a hexane recovery system, it was not possible to take full advantage of the effectiveness of the method. Moreover, this process is simple and quick, repeatable and reproducible results. However, as evidenced by the bulk extraction results, the solvent extraction method proved to be a vastly more time consuming and labour efficient process than mechanical process in the given circumstances.

5. Conclusion

Seed processing, drying and oil extraction methods have a significant impact on oil yields and the success of beauty leaf as future generation biodiesel feedstocks. Treating the seed kernel to optimum moisture content was found to be crucial to the success of both mechanical and solvent extraction. It is also noted that the grated kernels provided higher oil yields than the whole kernels in the mechanical extraction process. Kernels prepared with 15% moisture content provided the highest oil yields for both extraction processes. Mechanical extraction using the screw press was found ineffective with relatively lower oil yields for a great deal of effort. On the other hand, chemical extraction using n-hexane as a solvent was found to be very effective with higher oil yields; however, due to the lack of hexane recovery system, it was not possible to take full benefits of the effectiveness of the method. Therefore, it is strongly recommended to use n-hexane recovery system to reduce the cost of beauty leaf bio-oil production through solvent extraction method.

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