ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 14 (3): 146-151, 2015
ISSN 1812-5379

CrossMark
click for updates

ansinet
Asian Network for Scientific Information

RESEARCH ARTICLE OPEN ACCESS

DOI: 10.3923/ja.2015.146.151

Study on the Potential of Land Utilization for Energy Plantation as Biodiesel Feedstock: Case Study of Andalas University Campus at Limau Manis

[1]Fadjar Goembira, [2]Chairul Mahmud and [1]Ade Fitriani
[1]Department of Environmental Engineering, Faculty of Engineering, Andalas University,
[2]Department of Biology, Faculty of Mathematics and Natural Science, Andalas University, Kampus Unand Limau Manis Padang, 25163, Indonesia

ARTICLE INFO

Article History:
Received: May 11, 2015
Accepted: July 07, 2015

Corresponding Author:
Fadjar Goembira
Department of Environmental Engineering, Faculty of Engineering, Andalas University, Padang, 25163, Indonesia

ABSTRACT

This study was conducted to identify potential energy plants as biodiesel feedstocks atan Indonesian university campus. Plant identification and selection of the most potential oil-plant were done by purposive sampling and goal achievement methods, respectively. Some plant oil properties, i.e., seed-oil content, water content, free fatty acid content and fatty acid profile, were evaluated by laboratory analysis. It was found out that five common energy plants were identified as existing plants, i.e. *Terminelia cattapa* Linn, *Mimusops elengi* Linn, *Vitex pubescens* Vahl, *Leucaena leucocephala* Lam and *Swietenia mahagoni* Jacq. The seed-oil content varies from 10.83-70.19 wt%, while the water contents were in the range of 1.56 and 3.75 wt%. As for the free fatty acid content was between 1.67 and 3.64 wt%. According to the evaluation of seed and plant-oil properties, *Terminelia cattapa* Linn. is recommended for planting in unused space of Andalas University with the total area of approximately 9.04 ha. The planting of *Terminelia cattapa* Linn at the unused area together with the existing energy plants is estimated to produce 5,546.040 L year^{-1}, oil that can potentially be converted into biodiesel.

Key words: Biodiesel, FAME, potential feedstock, unused campus Area, Andalas University

INTRODUCTION

At the moment, energy-related problems are mainly related to the use of fossil-derived fuels. The fuel price increases due to imbalance demand and supply. Moreover, there are also issues with air pollutant emissions and the increase of greenhouse gases that triggers global warming.

Consequently, many research projects are now focused on reducing fossil fuel dependency by looking for alternative non-fossil-derived fuels. For instance, research on the development of biodiesel is done worldwide, which includes feedstock, its potential and the means of production.

Biodiesel is an alternative fuel that is made from renewable resources such as plant oils and animal fats. The resources are biodegradable and non-toxic, which have low air pollutant emission and give positive impacts to the environment (Zhang *et al*., 2003). The use of plant oil as an alternative fuel had been done in earlier 1980. Plant oils have the potential to substitute a fraction of petroleum-based engine fuels in the near future (Demirbas, 2003). The advantages of plant oil as a diesel fuel are the availability of raw materials, renewable property, high efficiency of combustion, low sulfur contents, biodegradable, reducing the dependency on petroleum, high flash point and inherent lubricity in the neat form (Knothe *et al*., 2006).

The plant, which will be used as raw materials of biodiesel should be non-edible oil, in order to avoid a competition of alternative energy source and food supply. Non edible plant oils like *Jatropha*, rubber, tall oil and micro algae are available in developing countries and it is more economical than edible

Table 1: Fatty acid composition of oils

Oils (refined)	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3
Soybean (US)	11.9	0.3	4.1	23.2	54.2	6.3
Palm (Malaysia)	42.6	0.3	4.4	40.5	10.1	0.2
Rapeseed (EU)	3.8	0.0	2.0	62.2	22.0	9.0
Sunflower (EU)	6.4	0.1	2.9	17.7	72.9	0.0
Cottonseed (China)	28.7	0.0	0.9	13.0	57.4	0.0
Tallow (US)	23.3	0.1	19.3	42.4	2.9	0.9
Tall oil	38.8	9.7	7.3	23.1	0.4	5.8

Source: Kralova and Sjoblom (2010)

oil. In transesterification of vegetable and fats oils for biodiesel production, free fatty acids and water content always produce negative effects. The existence of free fatty acids and water content causes soap formation consumes catalyst and reduces catalyst effectiveness (Demirbas, 2007).

Plant oils consist of triglycerides that have a high heat value and can be converted to biodiesel by transesterification with methanol reaction. Palm and kernel oils consist of 20-60% oil content. Triglycerides composition from plant oil is presented in Table 1. From Table 1 we can observe that palmitic acid (C16:0) and stearic acid (C18:0) are two common saturated fats that are found in plant oils. Moreover, Oleic acid (C18:1) and linoleic acid (C18:2) and linolenic acid (C18:3) are unsaturated fat acid that are mostly found in plant oils.

Andalas University as one of state universities in Indonesia is located in Padang, West Sumatera Province. Andalas University has a campus area of approximately 500 ha. The presence of unused space in Andalas University can potentially be used for planting energy plants. This study was done in order to identify potential energy plants to be planted in the unused space of Andalas University Campus at Limau Manis.

MATERIALS AND METHODS

Materials: Plant-seeds were collected from the common plants that were found in Andalas University campus. Moreover, some chemicals used in this study were n-hexane, 2-propanol, toluene, potassium hydroxide,phenolphthalein and methanol, which all were with analytical purities, i.e., higher than 99%. All chemicals were obtained from Merck Chemicals, Indonesia.

Methods

Identification and selection of plant oils: The common oil producing plants were identified by using Purposive Sampling Method, while for the selection of potential oil plant was determined by Goal Achievement Method.

Seed oil extraction and seed oil content: Collected plant seeds were firstly ground by a blender and afterwards they were heated at 105°C for 3 h to remove the water content. Oils were extracted from the seeds by using Soxhlet extractor for 10 h with hexane as the solvent. The oils were further analyzed gravimetrically to know seed-oil contents. If necessary, the oils were preserved by purging the bottles with nitrogen gas and by placing them in a refrigerator before analyzing their properties.

Plant-oil property check: Some plant-oil properties, i.e., water content, acid value and fatty acid profile were examined in this study. Water content was measured by gravimetric method, while the measuring of acid value was done according to AOCS method Cd 3-63 (AOCS., 2009). Fatty acid composition was analyzed by using GC, equipped with an FID detector. Column oven temperature was 70°C. Split injector temperature was 200°C. Flow control mode was linear velocity at 51.6 cm sec^{-1}. The oven temperature was programmed at 70°C for 3 min and finally increased to 300°C at 2 min.

Measurement of unused space: The determination of unused space at Andalas University Limau Manis campus was done by firstly using Google Earth and followed by direct observation and measurement for cross-checking the results.

RESULTS AND DISCUSSION

Common plant oils in andalas university campus: Five common plant oils in Andalas University campus were identified, which are: *Terminelia cattapa* Linn, *Mimmusops elengi* Linn, *Vitex pubescens* Vahl, *Leucaena leucocephala* Lam *and Swietenia mahagoni* Jacq.

Potential land area: Based on the measurement, it is estimated that there is around 9.04 ha of unused space in Andalas University campus at Limau Manis. Figure 1 presents the locations of unused space and their corresponding land area size.

Characteristics of seeds and plant oils: The characteristics of seeds and plant oils are presented in Table 2. The oil contents of *Terminelia cattapa* L was 32.20%, which is in agreement to that of reported by Agatemor (2006), i.e., 40.15%. The water content of the oil was 3.75%, while the Free Fatty Acid (FFA) content was 2.14%. As for *Mimusops elengi* L the oil content was 31.61% that is similar to the one reported by Sharma *et al*. (2009), i.e., 32.34%. The water content of the oil was 2.86±0.27%, while the FFA content was 3.64%.

With regards to *Vitex pubescens* V, the oil content, water content and FFA were 10.83, 3.14 and 2.74%, respectively. As for *Leucaena leucocephala* L, seed oil content was 21.50%, while the water content and FFA of the oil were 2.05 and 3.36%, correspondingly. Lastly, *Swietenia mahagoni* J have the oil content, water content and FFA of 70.19, 1.56 and 1.67%, respectively.

Fig. 1: Andalas University campus *Red hatched areas are unused spaces

Table 2: Seed and plant oil properties

Properties (%)	*Terminelia cattapa* L	*Mimusops elengi* L	*Vitex pubescens* V	*Leucaena leucocephala* L	*Swietenia mahagoni* J
Seed oil-content	32.20	31.61	10.83	21.50	70.19
Water content	3.75	2.89	3.14	2.05	1.56
FFA content	2.14	3.64	2.74	3.36	1.67

The fatty acid compositions of all plant oils in this study are presented in Fig. 2. The most dominant fatty acids for *Terminelia cattapa* L were C16:0 (40.16%) and C18:1 (29.04%). The unsaturation level of the fatty acids in this plant oil was found to be 50.91%, while the total saturated fatty acids were 49.09%. It is in a good agreement with that reported by Adewuyi *et al*. (2011) who stated that unsaturation level in *Terminelia cattapa* L was found to be 55.08%, while the saturated fatty acids were 44.92%.

On the other hand, the most dominant fatty acid for *Mimusops elengi* L were C16:0 (40.80%) and C18:2 (29.83%). The unsaturation level of the oil was found to be 54.32%, while the saturation level was found to be 45.68%. The comparison of unsaturated and saturated level is comparable to what Sharma *et al*. (2009) have studied. Furthermore, in *Vitex pubescens* V the most dominant fatty acids were C16:0 (37.38%) and C18:1 (36.91%). The unsaturation level of the oil was found to be 48.94%, while the saturation level was found to be 51.06%. The fatty acid composition of *Leucaena leucocephala* L seed-oil was dominated by C16:0 (34.47%) and C18:1 (26.53%). The unsaturation level of the oil was found to be 55.21%, while the saturation level was found to be 44.79%. Finally, the fatty acid composition of *Swietenia mahagoni* J oil were mostly C16:0 (33.06%) and C18:1 (27.98%). The unsaturation level of the oil was found to be 59.96%, while the saturation level was 40.04%. According to Azam *et al*. (2005), the composition of fatty acid was dominated by C18:1(56%) and the saturated level was known

Table 3: Base criteria scoring in goal achievement method

Criterias	*Terminelia cattapa* L	*Mimusops elengi* L	*Vitex pubescens* V	*Leucaena leucocephala* L	*Swietenia mahagoni* J	Score
Oil produced (kg/9.04 ha)	1,446.40	1,345.14	135.71	351.20	506.24	15
Harvesting time (years)	3-5	3-5	3-5	3-5	10-15	25
Root type	Taproot	Taproot	Taproot	Taproot	Taproot	20
Leaf size (cm^2/tree)	1,270,679	258,093	259,200	116,122	225,600	20
Specific requirement for cultivating	None	None	None	None	None	20

Table 4: Normalized effectiveness measure and weighted final score

	Normalized effectiveness measure					
Criterias	*Terminelia cattapa* L	*Mimusops elengi* L	*Vitex pubescens* L	*Leucaena leucocephala* L	*Swietenia mahagoni* J	Scores
Oil produced	100	100	80	80	85	15
Harvesting time	95	95	95	95	85	25
Root type	85	85	85	80	80	20
Leaf size	100	100	100	100	100	20
Specific requirement for cultivating	100	100	100	100	100	20
Total						100

	Weighted final score				
Criterias	*Terminelia cattapa* L	*Mimusops elengi* L	*Vitex pubescens* L	*Leucaena leucocephala* L	*Swietenia mahagoni* J
Oil produced	1,500	1,500	1,200	1,200	1,275
Harvesting time	2,375	2,375	2,375	2,375	2,125
Root type	2,000	1,700	1,700	1,600	1,600
Leaf size	2,000	2,000	2,000	2,000	2,000
Specific requirement for cultivating	2,000	2,000	2,000	2,000	2,000
Total	9,875	9,575	9,275	9,175	9,000

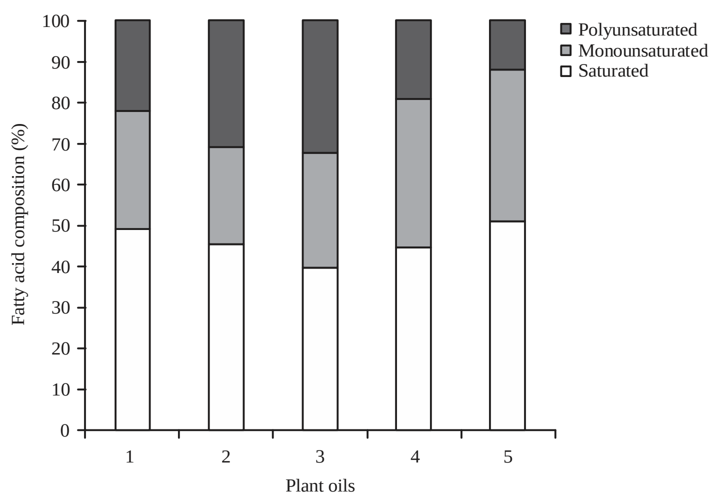

Fig. 2: Fatty acid composition of most found plant oils in Andalas University campus

to be 27.9%, while the unsaturated level was 72.1%. The difference in fatty acid composition were observed, which is possibly caused by the difference of the geography where the plants were grown.

Selected plant oils for unused land areas: Although, there are five common plant oils that were found in Andalas University campus, only the most potential one that will be recommended to be planted in unused area. Some criteria that were used in determining the most potential one are amount of oil produced, harvesting time, the types of root, leaf area size and specific requirements during cultivation are presented in Table 3.

The selected plant with the highest weighted final score is presented in Table 4. According to Table 4, selected plant oil is *Terminelia cattapa* L, which will be recommended to be planted in unused area of Andalas University campus.

Table 5: Oil yield from existing and recommended oil-producing plants

Plants	Yield (kg/HT*)	Oil density (kg L^{-1})	Oil volume (L/HT*)	Harvesting time (month)	Oil volume (L $year^{-1}$)
Existing plants					
Terminelia cattapa L	515.735	0.890	579.478	6	1,158.955
Mimusops elengi L	76.623	0.890	86.093	2-2.5	413.245
Vitex pubescens V	3.300	0.890	3.708	2-3	14.831
Leucaena leucocephala L	49.930	0.890	56.101	3-4	168.303
Swietenia mahagoni J	464.396	0.890	521.795	10-12	521.794
				Sub total	2,277.130
Recommended plant					
Terminelia cattapa L	1,454.670	0.890	1,634.460	6	3,268.910
				Sub total	3,268.910**
				Grand total	5,546.040**

*HT: Harvesting time **After 3-4 years

Table 6: Mixture of water content and FFA content

Plant oils	Volume (L)	Water content (%)	Mixture of water content	FFA (%)	Mixture of FFA
Terminelia cattapa L	413.246	2.858	1,181.057	3.641	1,496.967
Mimusops elengi L	4,427.870	3.754	16,622.224	2.143	9,442.870
Vitex pubescens V	168.303	2.053	345.526	3.362	562.947
Leucaena leucocephala L	14.819	3.137	46.527	2.741	40.908
Swietenia mahagoni J	521.794	1.556	811.911	1.673	868.574
Total	5,546.045		19,007.246		12,412.262

Estimation of oil produced: Prediction of plant oil produced consists of the production of oil from existing plants and from the recommended plant oil planted at unused space in Andalas University Campus. The results are presented in Table 5.

According to Table 5, the potential of plants oils is estimated around 2,277.130 L $year^{-1}$ from existing plants and around 3,268.910 L $year^{-1}$ from the recommended plant to be planted at unused areas. It can be estimated that around 5,546.040 L $year^{-1}$ plant oil can be produced at Andalas University Campus after 3-4 years of the recommended plant cultivation.

Environmental benefit: By planting energy plants in unused space area at Andalas University campus, it can help to increase environmental quality through the absorption of CO_2 by energy plants and the improvement of water infiltration in the unused area by the effect of surface run-off reduction due to the plantations. According to Yelza *et al*. (2009), it can be predicted that the planting of energy plants in unused area at Andalas University campus potentially decrease run off coefficient from 0.45-0.40. As for the potential CO_2 absorption, which refers to a research by Suwanmontri *et al*. (2013), it can be estimated that *Terminelia cattapa* L will potentially absorb 51.13 µmol. m^{-2} sec^{-1} or 3,055.145 ton CO_2/year.

Biodiesel production process: Water and FFA contents of all plant oils that are presented in Table 6 are used as the base for determining recommended biodiesel production process. Referring to Ma and Hanna (1999), the water content of biodiesel feedstock should be kept below 0.06% and FFA content of should be kept below 0.5%, in order to get the best conversion process.

The value of the mixture of water content.

$$Cc = \frac{\sum_{i=1}^{n=5} CiVi}{\sum V}$$

$$Cc = \frac{19,007.246}{5,546.045}$$

$$Cc = 3.427\%$$

The value of the mixture FFA content.

$$Cc = \frac{\sum_{i=1}^{n=5} CiVi}{\sum V}$$

$$Cc = \frac{12,412.262}{5,546.045}$$

$$Cc = 2.237\%$$

According to Ma and Hanna (1999), the biodiesel process production for oil feedstock that has water content and FFA more than 0.06 and 0.5% must be treated by two step production process, i.e., esterification and transesterification. Figure 3 shows the recommended biodiesel process production according to the quality of potential biodiesel feedstock in Andalas University campus.

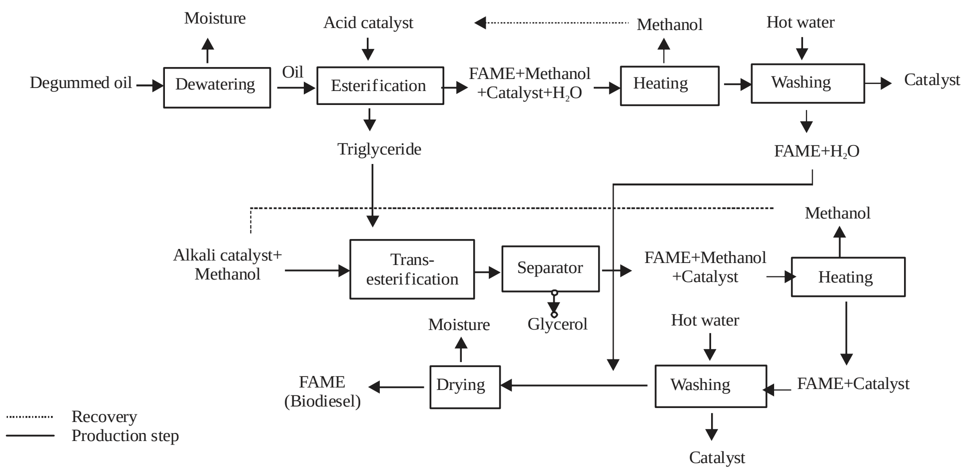

Fig. 3: Recommended biodiesel production process

CONCLUSION

Andalas University that has large campus area can potentially use biodiesel for its campus bus operation. In order to produce biodiesel, some unused space in the campus can be planted with potential energy plants. Based on this research, there are five existing energy plants suitable for biodiesel feedstock. Among those plants, *Terminelia cattapa* L. is recommended as the most potential one according to Goal Achievement Method, due to its high seed oil-content and its fatty acid profile that will not considerably influenced the cold flow properties of the produced biodiesel. Planting *Terminelia cattapa* L. is also able to decrease run off coefficient of present unused space area and to increase CO_2 absorption ability within the campus area, which give additional advantages to the environment.

ACKNOWLEDGMENT

This study was completed under financial support from the Faculty of Engineering, Andalas University under contract no. 003/PL/SPK/PNP/FT-Unand/2013, for all of which the authors highly acknowledge.

REFERENCES

AOCS., 2009. Official method Cd 3d-63. AOCS Methods for biodiesel feedstock quality. American Oil Chemist Society, USA.

Adewuyi, A., R.A. Oderinde and D.F.K. Ojo, 2011. Production of biodiesel from *Terminalia catappa* seed oil with high free fatty acids using an acid-catalyzed pretreatment step. Int. J. Sustain. Energy, 30: S59-S65.

Agatemor, C., 2006. Studies of selected physicochemical properties of fluted pumpkin (*Telfairia occidentalis* Hook F.) seed oil and tropical almond (*Terminalia catappia* L.) seed oil. Pak. J. Nutr., 5: 306-307.

Azam, M.M., A. Waris and N.M. Nahar, 2005. Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. Biomass Bioenergy, 29: 293-302.

Demirbas, A., 2003. Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: A survey. Energy Convers. Mange., 44: 2093-2109.

Demirbas, A., 2007. Alternatives to petroleum diesel fuel. Energy Sour. Part B: Econ. Plann. Policy, 2: 343-351.

Knothe, G., C.A. Sharp and T.W. Ryan, 2006. Exhaust emissions of biodiesel, petrodiesel, neat methyl esters and alkanes in a new technology engine. Energy Fuels, 20: 403-408.

Kralova, I. and J. Sjoblom, 2010. Biofuels-renewable energy sources: A review. J. Dispersion Sci. Technol., 31: 409-425.

Ma, F. and M.A. Hanna, 1999. Biodiesel production: A review. Bioresour. Technol., 70: 1-15.

Sharma, S., S. Gangal and A. Rauf, 2009. Lipase mediated hydrolysis of *Mimusops elengi* and *Parkinsonia aculeata* seed oils for the determination of positional distribution of fatty acids. Ind. Crops Prod., 30: 325-328.

Suwanmontri, C., C. Kositanont and N. Panich, 2013. Carbon dioxide absorption of common trees in Chulalongkorn University. Mod. Applied Sci., Vol. 7.

Yelza, M., J. Nugroho and S. Natasaputra, 2009. Pengaruh perubahan tataguna lahan terhadap debit limpasan drainase di kota bukittinggi (in Bahasa Indonesia). Research Paper, Institut Teknologi Bandung.

Zhang, Y., M.A. Dube, D.D. McLean and M. Kates, 2003. Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. Bioresour. Technol., 90: 229-240.