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Waste-to-Wealth: Energy Pack as an Integrated Biofuel

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The global trend is moving towards green energy generation and application. However, there exists a transition period where the usage of fossil fuel is unavoidable while green energy is being developed. A transitional level of fuel – Energy Pack is introduced. Energy Pack is an industrial waste oil integrated biofuel, which the existing biofuel is 'packed' with industrial oil for improved heating value. The feasibility of producing this transitional level of fuel is investigated and the energy potential of the product is studied. The integration of Energy Pack production process into the existing biofuel generation facilities is modelled and its energy performance is studied. Besides, the absorption correlation of industrial oil into the biofuel is studied. The physical elements and properties of Energy Pack are compared to the existing biofuels. In addition, the incineration impact of Energy Pack is investigated. The introduction of Energy Pack gives one solution to industrial waste management as well as improving the heating performance of the existing biofuel.

1. Introduction

The current world is developing towards the generation of renewable energy. However, it is stated in World Energy Outlook 2012 that fossil fuel remains as the main source of energy despite the rapid progression of renewables substitution (WEO, 2012). Furthermore, the global oil consumption is predicted to grow steadily as the growth oil in consumption in emerging economies, especially the transport sector in China, India and Middle East, outweighs reduced demand in Organisation for Economic Co-operation and Development (OECD) (WEO, 2012). Despite the advancement of technology, EPA (2013) states the fact that 200 million gallons of used oil are improperly disposed every year; whilst, API (2013) reveals that 2 gallons of used oil can generate adequate electricity to upkeep an average household for almost 24 hours.
However, it shall be noted that oil does not wear out but it gets contaminated. Used oil can be kept recycling and used repeatedly without losing its lubricating capability. Nevertheless, some used oil is recycled to be used as fuel oil instead of being re-refined (Texas Commission on Environmental Quality, 2005).
On the other hand, advanced country such as United Kingdom has prohibited the incineration of waste oil since 2005 (Norris et al., 2006). Waste oil incineration is forbidden unless filtering facilities is installed to upgrade existing waste oil incinerating plant to meet the requirement of Waste Incineration Directive (DEFRA, 2012). Nevertheless, other developing countries have a portion of waste oil which is ultimately being incinerated for power generation or heat recovery.
Other than power generation using fossil fuel, increasing practice of sustainability has led to the development of renewable energy sources and waste-to-energy schemes (Čuček et al., 2013a). There have been researches on waste-to-energy by Ofori-Boateng et al. (2013) for electricity generation using municipal solid waste, Ionescu et al. (2013) for an integrated municipal solid waste with advance waste pre-treatment, Ng et al. (2014) for optimal municipal solid waste allocation and supply network and so on. Furthermore, Brunner and Rechberger (2014) identified waste-to-energy as one key element for sustainable waste management. However, the researches on waste-to-energy were mainly focused on municipal solid waste. Recently, Rentizelas et al. (2014) combined the municipal solid waste and biomass system for energy generation. Yet, less has related industrial waste to any waste-to-energy scheme.

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This work is a continuation work to the green strategy proposed by Lam et al. (2013) which a green strategy for sustainable waste-to-energy supply chain is proposed. Energy Pack which is an industrial waste oil integrated biomass fuel is introduced as one energy strategy. The integration of waste oil into the existing biomass-based solid fuel acts as one solution to waste oil management. Since both biomass-based solid fuel and waste oil will be incinerated separately if they were not incinerated together, the incineration of Energy Pack generates no net increase in emission to the atmosphere.

Energy Pack is formed by absorption waste oil into the biomass. Biomass has shown good potential to be used as bio-absorbent. Pelosi et al. (2013) has studied the performance of *Salvinia natans* biomass to absorb acid orange 7 dye in textile industry and Lima et al. (2013) has investigated the ability of *Pistia stratiotes* biomass to absorb lead and chromium. In this study, the oil absorption ability of palm biomass-based solid fuel is investigated. This study verifies the oil containment ability of palm biomass and hence the practicability of Energy Pack.

2. Experimental methodology

2.1 Materials

The main raw material used in this work is palm pellet from Global Green Synergy Sdn. Bhd. (GGS, 2014) with moisture content less than 10 %, diameter between 8 to 10 mm and calorific value about 19 MJ/kg. Pellet samples of 50 g and 100 g are prepared to be immersed into the waste engine oil. Waste engine oil is collected from a random automobile service centre in Malaysia. The waste engine oil used has a calorific value about 40 MJ/kg.

2.2 Experimental procedure

Since the absorption does not involve selective ions absorption, physical bulk absorption process is carried out. The experiment is conducted by mixing 100 g of palm pellet with excess waste engine oil at room temperature. None agitation is required as bulk absorption is carried out. The pellet is sieved out of the waste oil and weighted every 2 min interval to obtain the weight of waste oil absorbed into the biomass. The experiment is then repeated with 50 g sample.

3. Results and discussion

Figure 1 shows the oil absorption trend of waste engine oil into palm pellet to form Energy Pack. It can be observed that oil absorption occurs within the first few minutes when pellet comes into contact with oil. Despite the fast oil absorption rate of the pellet employed, the oil absorption rate and the final volume of oil being absorbed is highly dependent on the pellet's surface area available and its porosity. Pellet with more surface area per unit volume allows more vicinity for oil absorption at the pellet's immediate oil contacting surface. In addition, pellet of higher porosity facilitates faster oil absorption into the inner part of the pellet. In this study, the pellet at the end of measured time achieves almost full oil penetration to its inner part, as shown in Figure 2.

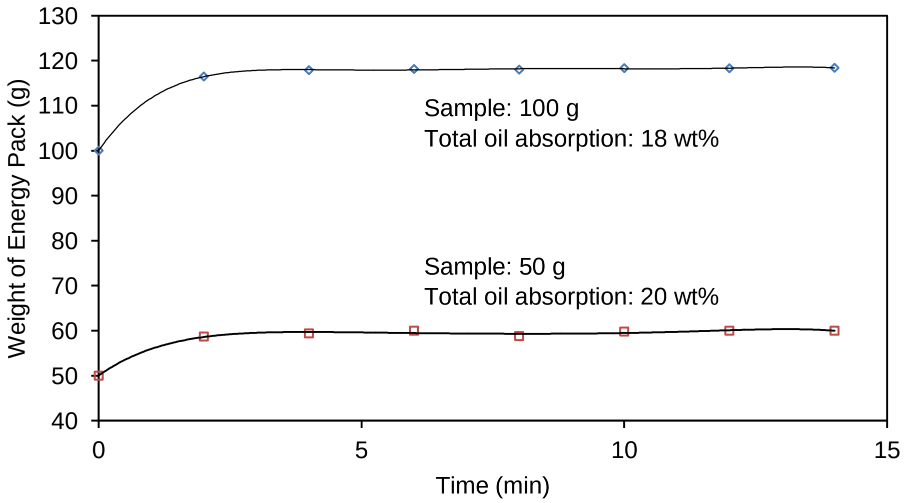

Figure 1: The oil absorption rate of waste oil into palm pellet

Figure 2: Palm pellet (light brown – left) vs. Energy Pack (dark brown – right) – after waste engine oil absorption to inner layer of pellet

From Figure 1, a maximum of 18 wt% of waste oil is absorbed by the pellet for 100 g sample; whilst, 20 wt% of waste oil is absorbed by the pellet for 50 g sample. This value may be increased if pellet with higher porosity is employed and full penetration of oil through the inner part of pellet is observed. In contrast, the amount of oil that is absorbed can diminish if highly dense pellet is used and the oil absorption time of the pellet will be prolonged to achieve equilibrium. Nevertheless, oil absorption into pellet is fast that equilibrium is almost achieved within 2 minutes in an environment of excess oil.

Despite the variation of oil absorption capacity of both samples, pellet in sample of 100 g achieves an oil absorption rate of 0.21 kg/m^2/min; while pellets in sample of 50 g achieves oil absorption rate of 0.23 kg/m^2/min. Note that these figures are calculated using the result obtained at time interval 2 min. This variation is minor and this variation can be resulted by the inconsistent length of pellets used, which higher count of pellets give addition area (cross-sectional area) for oil absorption.

After that, the density and heating value of Energy Pack is compared with the biomass fuel palm pellet, conventional fuel – coal and waste engine oil in Table 1. After the absorption of waste engine oil, Energy Pack contains higher density and higher heating value. However, these values of Energy Pack are obtained at oil absorption capacity of 15 wt%. From previous discussion, it has been highlighted that Energy Pack is able to contain more oil and thus higher heating value.

Table 1: Theoretical comparison of basic physical properties of palm pellet, Energy Pack (at 15 wt% oil absorption), waste engine oil and coal

	Phase	Density (kg/m^3)	Lower heating value (MJ/kg)
Palm pellet	1. Solid	2. 1,300 +/-	3. 19 +/-
4. Energy Pack	5. Solid	6. 1,500 +/-	7. 21 +/-
8. Coal (thermal coal)	9. Solid	10. 850 +/-	11. 25 +/-
12. Waste engine oil	13. Liquid	14. 880 +/-	15. 40 +/-

If palm pellet were produced to generate Energy Pack, the requirement of pellet quality can be lower down as porous pellet facilitates oil absorption. Figure 3 shows (a) palm pellet and (b) palm pellet after oil absorption. It can be seen that the pellet or Energy Pack produced does not disintegrate. However, a lower cap of pellet standard shall be maintained to uphold the product’s quality and longevity.

Palm pellet contains mostly organic components; whereas waste engine oil contains metals and hazardous components (Cal/EPA, 2004). The incineration of Energy Pack will emit hazardous emission. Some common components of emission resulted from the incineration of the conventional palm pellet and Energy Pack are listed in Table 2.Due to the existence of hazardous components in the flue gas, emission abatement technologies are needed to filter these components. Investment has to be made, if none was installed, to upgrade the current incineration station. This high cost of capital investment may reduce the favourability of the proposal. Nevertheless, the flexibility of Energy Pack may overcome this weakness, which is described in the next section.

Table 2: Common components in the emission from the incineration of palm pellet and Energy Pack

	Palm pellet	Energy Pack
Common components in emission	16. Ash 18. Moisture 20. Carbon dioxide / Carbon monoxide	17. Ash 19. Moisture 21. Carbon dioxide / Carbon monoxide 22. Sulphur oxides 23. Nitrogen oxides 24. Toxic metals 25. Chlorinated organics 26. Other organics (benzene, dioxin, etc.)

Figure 3(a): Palm pellet

Figure 3(b): Energy Pack – palm pellet after waste oil absorption

4. Flexibility of Energy Pack

Nonetheless, it shall be noted that unprocessed used engine oil contains high concentration of heavy metals (Dawn, 2009). These heavy metals are carcinogenic and upon incineration, the emission may be highly toxic with mutagenic property. This possibility may result in less favourable attraction to this study presented. However, the introduction of Energy Pack as an integration of oil into biomass for improved heating property does not limit to waste engine oil absorption. Potential candidates include other incinerable oil such as diesel, bio-oil, less impact waste oil and so on.

5. Conclusions

This work studied the oil absorption capability of palm pellet which leads to its potential to be further processed to produce Energy Pack. The Energy Pack which is an integration of biomass fuel and fossil fuel appears to be a highly potential transitional level fuel when the society is shifting the energy trend from fossil energy to renewable energy. The utilisation of waste oil for Energy Pack generation acts as another solution for industrial waste oil management. Energy Pack shows improved heating value (11 % increment in heating value) as compared to the conventional palm biomass fuel.
The study can be further extended to investigate the performance of oil absorption into the biomass with the addition of surfactant for improved absorption performance. Besides, assessment can be carried out to evaluate the quantitative character of emission from Energy Pack incineration. Life cycle assessment can be carried out to analyse the product; whilst, multi-objectives optimisation considering total footprints (Čuček et al., 2013b) and potential total site analysis (Varbanov, 2014) can be carried out to evaluate the product's environmental performance.

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