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Extraction of Biofuel from Orange Peel and its Characterization

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Abstract

Orange is one of the most popular fruits in the world which are eaten fresh and usually processed to make juice. But the production of orange juice generates substantial quantities of waste which represents about 50% of the raw processed fruit. Moreover, orange peels, being a waste material may create environmental problems because of the presence of biomaterials. So the aim of this paper is to represent the extraction of D-limonene from orange peels using solvent extraction method and also testing its ability to use as biofuel. As producing D-limonene (flammable Product, flashpoint- 50^{o}C) from orange peel is an imperative step in scaling up biofuel production so that it can become a significant alternative to traditional fossil fuels. The Physical properties of orange peel oil possess favorable density, viscosity, calorific value, flash point and fire point as biofuel. The density, calorific value, viscosity are found 789 kg/m^3, 41543 KJ/kg, 1.4 CP respectively.

Keywords: Orange Peel, D- limonene, Biofuel, Oil Extraction

1. Introduction

Biofuel is a fuel which is produced through existing biological processes, such as agriculture and anaerobic digestion. Biofuel can be derived directly from plants or indirectly from domestic and industrial wastes. In 2010, worldwide biofuel production reached 105 billion liters and biofuels provided 2.7% of the world's fuels for road transport [1]. The "International Energy Agency" has a goal for biofuels to meet more than a quarter of world demand for transportation fuels by 2050 to reduce dependence on petroleum and coal [2]. Orange peels consist of various soluble and non-soluble carbohydrate polymers which make it a perfect feedstock for biological conversion to biofuel [3]. Extracting the simple organic compound, D-Limonene from orange peels using the simple distillation method, when plant material is placed in boiling water, the essential oil in it evaporates with steam. Upon condensation of the steam and oil, the oil separates from water and can be collected [4]. The environmental pollution arises due to the orange peels can overcome by using the citrus oil extraction by steam distillation. The optimum amount of citrus oil 2.4ml/100g of orange peels can be extracted by steam distillation at the optimum condition of temperature 960^{o}C, time 60 minutes [5]. D-limonene (4R-isopropenyl-1-methylcyclohexane) is a monoterpene with a lemon-like odor and is a major constituent in several citrus oils [6]. Waste utilization from food processing industries is highly requisite and challenging task all around the globe. Generation of this waste is unavoidable because every time the finished product of the same consistency is produced without taking into consideration the amount of waste produced [7]. Citrus sinensis seed and peel oils were extracted by solvent extraction using n-hexane, after air drying and grinding. Essential oils in plant products have incredible applications in food, cosmetic and aromatherapy [8]. After studying the fossil fuel consumption of different countries it is evident that, the worldwide fossil fuel consumption including Bangladesh is increasing gradually. Cyclone power technologies has tested biofuel, D-limonene made from orange peels of its external combustion engine for hybrid cars for SAE commercial vehicle convention in Chicago [14]. Petroleum ether is used as solvent to extract oil from orange peel by solvent extraction method in this research.

2. Reasons for selecting orange peels

For research purpose, orange peels are selected due to following reasons-

- Orange (*Citrus sinensis*) is one of the most common fruit in the world.
- Orange peels are treated as waste material.
- Orange peels need minimal input or management.
- Orange peels provide ecological and environmental benefits.
- Orange peels offer scope of using new energy for the world.

The worldwide fossil fuel consumption for different countries is displayed below:

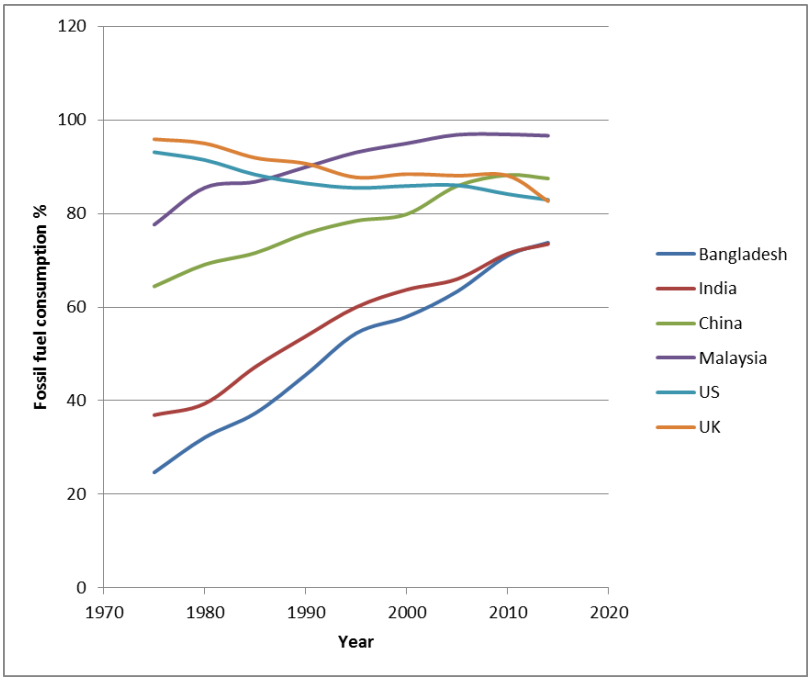

Fig. 1. Fossil fuel consumption of different countries [10]

The dependence of fossil fuel as a primary source of energy for domestic and industrial application by most countries of the world are increasing day by day which has led to global climate changes, environment degradation and human health problems. That's why it is very important to find an alternative fuel like biofuel. An international team of researchers has assembled an optimistic partnership named OPEC, says that orange peels are a perfect example of the remarkable potential that current food waste represents as a possible source of renewable biofuel.

3. Design of required apparatus

Distillation is a laboratory technique used for separating, purifying and isolating temperature sensitive liquids. The whole system consists of a distillation apparatus with two flasks, condenser and heater. The adapter connects to a condenser into which cold water is constantly passed through. The condenser leads into a collection flask for the recovered petroleum-ether. Since the solvent is highly volatile all the system is kept air-tight.

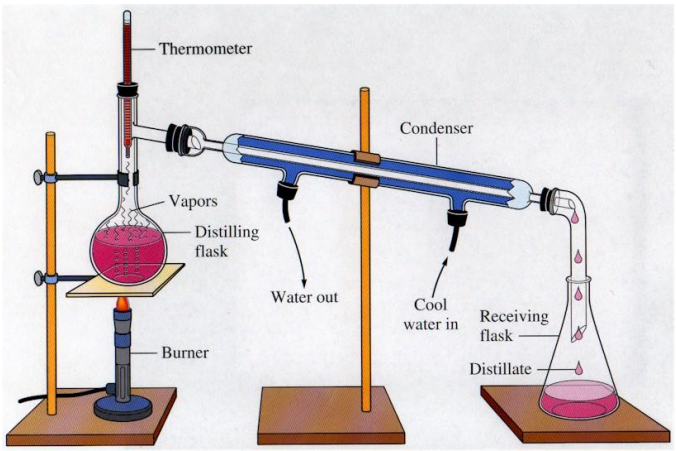

Fig. 2. Design of distillation apparatus [13]

4. Methodology

Solvent extraction method is basically a process which includes extracting oil from oil-bearing materials by mixing it with a low boiling solvent to extract the oil. The solvent extraction method recovers almost all the oils and leaves behind only 0.5% to 0.7% residual oil in the raw material. On the other hand, in the case of mechanical pressing the residual oil left in the oil cake may be anywhere from 6% to 14% [9]. Fig.3 shows the block diagram of the process of oil extraction from orange peels by solvent extraction method.

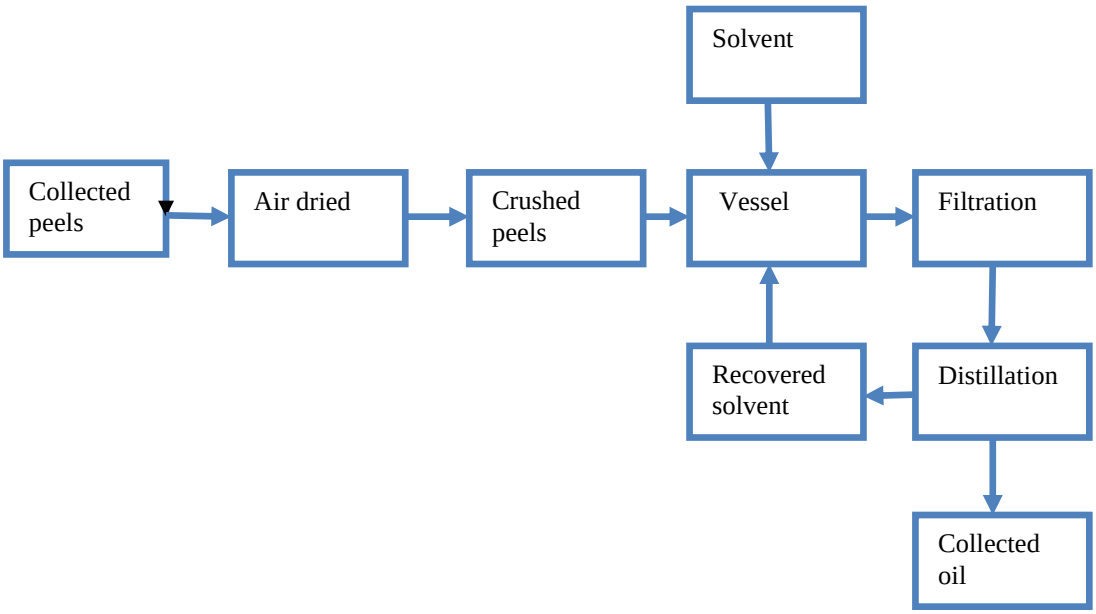

Fig. 2. Block diagram of oil extraction process

Oranges were collected from the local market of Rajshahi. The collected sample of orange peels is cleaned and pith is manually separated from the outer colored part of the peels. That is because of the reason that the majority of the oil present in them. Then the peels were cut into small pieces. After that the peels were air dried to remove the moisture content. The dried peels were then crushed into small particles with the aid of an electric crushing machine. About 700g crushed orange peel were mixed with petroleum ether at a ratio of 1:1.5 in a vessel and allowed to keep in rest for a day. After one day filtration was done with the help of a strainer.

(a) (b)

Fig. 3. (a) Mixture of petroleum-ether and orange peel (b) The distillation apparatus

Fig.3(b) shows the distillation apparatus. The mixture of petroleum-ether and orange peel oil were poured into the flask and heat was supplied to the distillation unit by temperature controlled basket heater. Anti-bumping granule was dropped into the flask to prevent the build of pressure in the flask. The boiling point of the petroleum-ether is very low, that's why petroleum-ether starts to evaporate earlier than the peel oil. After condensing the petroleum-ether was recovered into the round bottom flask attached at the right side of the

distillation apparatus and the orange peel oil still remain at the left side flask. The residual petroleum-ether is allowed to evaporate by keeping open the flask for several times. After the extraction, the oil was transferred into a measuring cylinder and the weight of the oil was determined by weighing the oil and the cylinder and subtracting the weight of empty cylinder. The percentage yield was determined. The flash point and fire point were also determined.

Fig. 4. Collected orange peel oil

5. Result and Discussion

The density of peel oil was determined by measuring 19 mL of the oil samples into a pre-weighed measuring cylinder. The density was 842kg/m^3. The obtained orange peel oil has a brownish-yellow color (Figure 4) similar to the color found in "African journal of microbiology research" [8]. The percentage of the oil acquired in this research is 23.33% of the peel.

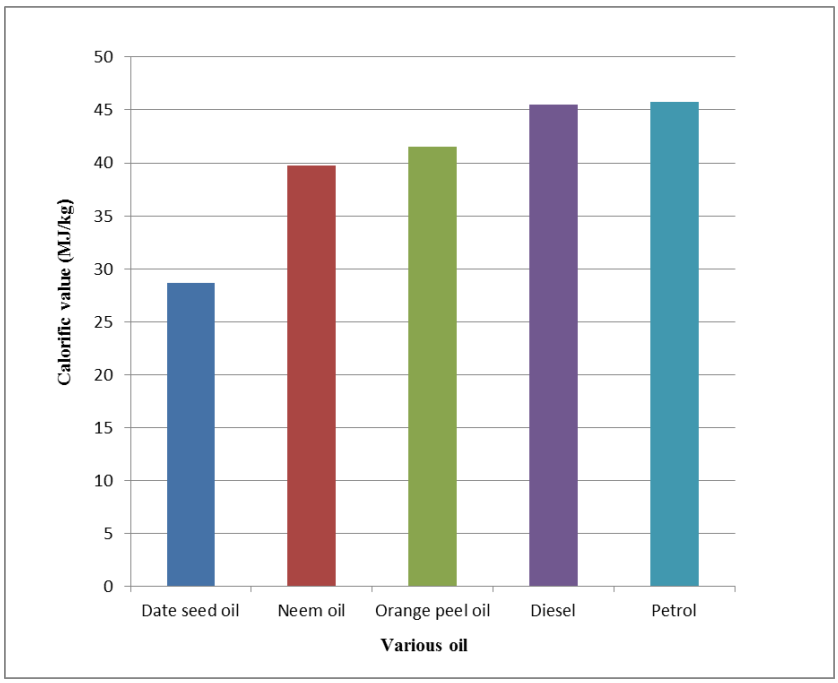

Fig. 5. Comparison of calorific value of different oils [15]

The higher the calorific value is a greater indication for using oil as fuel. Fig.5 shows that the calorific value of orange peel oil is 41543KJ/kg, which is lower than the diesel but it may be used as fuel at different purposes.

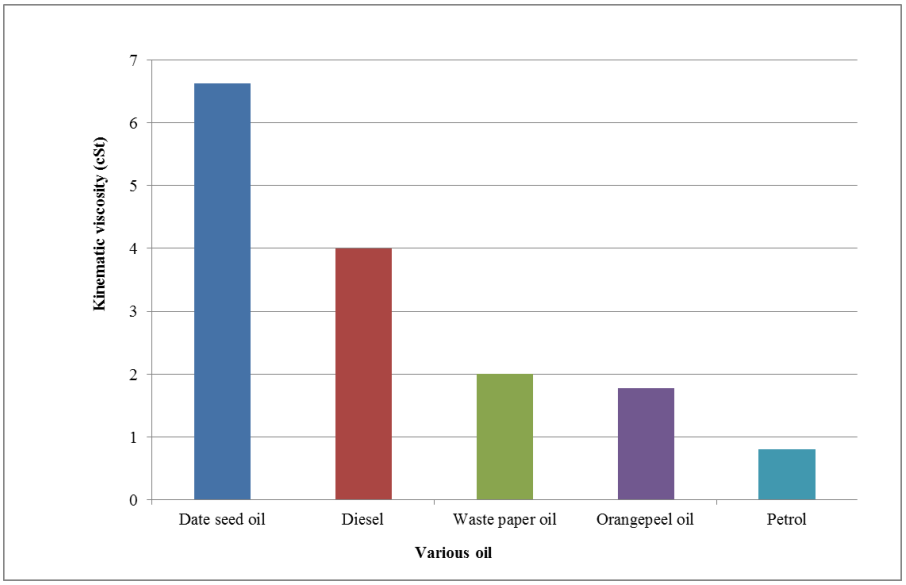

Fig. 6. Comparison of kinematic viscosity of different oils [15]

Viscosity is the vital property among all the fuel properties. Lower the viscosity of the oil is easier to pump and atomize in order to achieve finer droplets for proper mixing. From the figure 6 it can be seen that the kinematic viscosity of orange peel oil is favorable than other oils. Hence the extracted oil can be used as fuel at different purposes.

Table 1. Several fuel properties of different oil [11], [12]

Property	Orange peel oil	Diesel	Petrol
Density (kg/m^3)	789	835	749
Calorific value (kJ/kg)	41543	45500	45800
Kinematic viscosity (cSt)	1.77	2 to 6	0.80
Flash point (^0C)	50	52 to 96	-43
Fire point (^0C)	61	62 to 106	-13 to -23

6. Conclusion

In this research, solvent extraction method is used to extract oil from orange (*Citrus sinensis*) peels and various characteristics of the oil were determined. The extracted oil obtained from orange peels was about 23.33% wt. of feed materials. The higher calorific value (41543KJ/kg) of extracted orange peel oil is lower than conventional fuels like diesel. It can also be noted that the calorific value of orange peel oil is satisfactory than other oils. The density ($789kg/m^3$) of the extracted oil slightly differs from the value of diesel oil. The kinematic viscosity (1.77cSt) and dynamic viscosity (1.4CP) of the extracted oil are lower than that of diesel. The flash point and fire point of the extracted orange peel are 50^0C and 61^0C respectively. The lower value of flash point and fire point indicates the high quality of oil. The entire citrus waste is converted to valuable and environmentally friendly products, while it can significantly reduce the disposal of citrus waste. After all the investigations performed, it can be said that the solvent extraction method is suitable for extracting bio-oil from orange peels and all the characterized values match the criteria of being an engine fuel.

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