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Evaluation of physiochemical and tribological properties of rice bran oil – biodegradable and potential base stoke for industrial lubricants

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ABSTRACT

The poor biodegradability of petroleum oils pressurizes the industry to develop ecofriendly biodegradable lubricants from agricultural feed stocks. The biodegradability, renewability, low toxicity and excellent lubricating performance of vegetable oils are the main reason behind the use of vegetable oil in the upcoming bio lubricant formulations. The vegetable oil generally has high flash point, fire point, high viscosity index, high lubricity and low evaporative losses. The properties of vegetable oil mainly depend on the nature (saturated/unsaturated) and composition of fatty acids present in the vegetable oils. In this paper, we are analyzing the feasibility of using rice bran oil as biodegradable lubricant base oil. The rheological, thermal, chemical and tribological properties of rice bran oil have been evaluated and conducted a gas chromatographic technique to understand its fatty acid profile. The oxidative stability was evaluated by hot oil oxidation test and differential scanning calorimetry. The coefficient of friction and wear scar dimension were evaluated by using a Four Ball Tester. The physiochemical and thermal properties of rice bran oil are found to be good compared to other vegetable oils and the commercially available mineral oil, SAE20W40. Rice bran oil has good frictional properties compared to SAE20W40 but the wear scar diameter is more for rice bran oil and can be improved by adding proper anti wear additives.

1. Introduction

The fats and oils derived from animals and vegetable oils were the main sources of lubricants during 19th century. Modern lubricants are mainly based on mineral oil because of their cheap price and overall performance. At the end of 20th century, people realize the toxicity and non biodegradability of mineral oils. The spilling and throwing of used mineral oil are real threats for fishes, plants and wild life (Tamada et al., 2012; Aluyor and Ori-jesuee, 2009). The physiochemical properties of sand are changing due to the presence of mineral oils (Kayode et al., 2009). Thus, at the end of 20th century industry started developing biolubricants to replace mineral oils. In US around 200 companies have registered for the development of bio lubricants for various applications (Bremmer and Plonsker, 2008). The vegetable oils are biodegradable, renewable, less toxic (Boyde, 2002), good lubricating performance and better thermal stability (Asadauskas and Erhan, 2000; Mobarak et al., 2014). Poor oxidative stability, high pour point and high coefficient of friction at elevated temperature are some of the main disadvantages of vegetable oil (Adhvaryu et al., 2004; Frewing, 1942). The bio lubricants are given greater consideration as renewable and potential source of energy in future especially in the developing countries like India. Many research works have been reported for various vegetable oils like coconut oil (Jayadas and Nair, 2006a; Mannekote and Kailas, 2011), soybean oil (Doll and Sharma, 2012; Erhan and Adhvaryu, 2002; Castroa et al., 2006), jojoba oil (Bisht et al., 1993), rapeseed oil (Arumugam et al., 2012; Zhang et al., 2000), pongamia oil (Bhat and Bekal, 2012) and sunflower oil (Quinchia et al.,. 2010; Campanella et al., 2010). Similar works have not yet identified with rice bran oil. Rice bran oil is popular in several countries such as Japan, India, Korea, China and Indonesia as cooking oil. The rice bran oil was usually refined by physical refining techniques. The bran is mixed with hexane and allowed to squeeze between heated rollers and the oil hexane mixture thus produced is heated to separate rice bran oil from hexane (Zullaikah et al., 2005). The rice bran Oil has more oxidative stability compared to other vegetable oils like sunflower oil, soybean oil, cotton seed oil and corn oil (Pasquini and Gonzaga, 2006) due to the presence of a natural anti oxidant called gama oryzanol. The recent studies show that rice bran oil is well suited for biodiesel (Zhang et al., 2013).

The aim of the present study is to evaluate the physiochemical, oxidative and tribological properties of rice bran oil and

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understand the feasibility of developing biodegradable lubricant for the industrial applications from the same. As an initial study, we have evaluated viscosity, viscosity index, flash point,fire point, pour point, thermal stability, oxidative stability and tribological properties and compared with a commercially available lubricant, SAE20W40. It is identified that rice bran oil is a potential candidate for bio lubricant formulations.

2. Materials and methods

2.1. Materials

The rice bran oil is extracted from the bran collected from Northern Kerala, India. The oil content of the bran available in this geographical area is about 12%. The refined rice bran oil is purchased from Kalady Rice Mill Consortium, Kerala. The crude oil is mixed with 1% phosphoric acid and 200 liters/ton water and is heated at 80 °C.The heated mixture is stirred for 20 min using a mechanical stirrer and the gum is separated by a centrifugal separator. The bleaching of the oil is done by adding 2.5% earth .The color of the oil is removed by this process. The oil is fed to a dewaxing chiller (18 °C) and kept there for 20 min and then filtered using cloth filter to remove wax. This bleached oil is atomized in to a rotating chamber so that the smell has been removed completely. The sunflower oil and coconut oil are collected from local suppliers in Calicut, India.

2.2. Fatty acid profile

The composition of fatty acids is very much important in vegetable oil lubricant formulation. The length of carbon chain in fatty acids is the main deciding factor in the case of coefficient of friction and wear. The composition of rice bran Oil was evaluated by Gas chromatography (GC/FID) as per IS548 using Agilant technology model 6890N. Gas chromatography is a commonly used method for separating components of a complex mixture. In Gas chromatographic analysis, the components in the sample are identified by comparing the retention times of peaks in the sample chromatogram to the retention time of standard compounds. We have used the above method for finding out the fatty acid profile of rice bran oil.

2.3. Rheological and chemical properties

The viscosity of all the oils was evaluated by Redwood Viscometer as per ASTMD2270. The viscosity should be optimum for all the applications. The less viscosity may cause more wear and more viscosity will cause more frictional loss (Bailey, 1958).

The main chemical characteristics of vegetable oils which control its lubricating properties are acid number, saponification value and iodine value. The acid number indicates the amount of base content required to neutralize the lubricant. This is a measure of free fatty acids in the sample. As the acid number increases the free fatty acid content also increases. The iodine number indicates the amount of unsaturated bonds present in the sample. Iodine value is expressed as the amount of iodine absorbed per gram of sample. Saponification number is the measure of alkali required to saponify all the triglycerides in the sample. The saponification value is expressed as the amount of potassium hydroxide in milligrams required to saponify 1 gram of oil. All these chemical properties of the rice bran oil along with other vegetable oil are evaluated based on IS: 548 (Part 1) –1964.

2.4. Thermal properties

The flash point indicates the safe working temperature of operation and volatility of the oil. The fire point is the lowest temperature at which the oil gets fired with the help of an external flame. The flash point and fire point were estimated by Cleveland open cup equipment as per ASTMD92. The high flash and fire point considerably reduce the risk of fire in case of lubricant leakage and provide safety on shop floors.

Pour point is another characteristic of the lubricant to assess the fluidity of lubricants at low temperatures. This property is important in cold countries and in winter season. Less pour point is more suitable for good lubricant. Differential scanning salorimetry (DSC) is an efficient method for investigating crystallization temperatures, as it is more accurate than the classical pour point or cloud point measurement (de Rodrigues et al., 2006). The differential dcanning calorimetry (DSC) measures the variation of heat flows associated with transitions in materials as a function of time and temperature in a controlled atmosphere. These measurements provide quantitative and qualitative information about physical and chemical changes involved during heating. The pour point has been estimated by DSC. The instrument used was Mettler Toledo DSC 822e with a temperature range of −40 °C to 240 °C.

The study of thermal degradation of rice bran oil along with sunflower oil, coconut oil and mineral oil SAE20w40 was carried out by Thermo gravimetric analysis using PerkinElmer STA 6000 with an operating range of 0 °C–500 °C. This analysis was conducted in nitrogen environment. The non isothermal Thermo gravimetric analysis was obtained with nitrogen flow rate of 20 ml/min using a platinum crucible with a heating range of 10 °C/min.

2.5. Oxidative stability

The physical and chemical properties will change due to oxidation and this may cause considerable changes in lubrication performance. The vegetable oils will decay during storage as well as application depending upon the fatty acid composition. The highly unsaturated fatty acids like lenoleic and lenolenic acid will reduce the oxidative stability. The saturated fatty acids will provide good oxidative stability but causes high pour point. The oxidative stability can be improved by chemical modifications like hydrogenation and epoxidation (Sharma et al., 2006; Hwang et al., 2003). Proper additives can also be used to improve the oxidative stability (Rizwanul et al.,. 2014). In this paper we are assessing the oxidative stability of rice bran oil in comparison with sunflower oil and commercially available mineral oil, SAE20W40 using hot oil oxidation test and differential scanning calorimetry. In hot oil oxidation test the accelerated aging of vegetable oil samples was simulated by storing the samples in a dark oven at 100 °C for 96 h. This method is based on the versions of American Oil Chemists Society (AOCS Cd-12-57) recommended practice (Ruger et al., 2002; Mannekote and Kailas, 2012).

2.6. Tribological properties

The coefficient of friction was evaluated for rice bran oil, coconut oil and the commercially available mineral oil, SAE20W40 by using Four ball Tester as per ASTMD 4172-94. The experiments were carried out at 75 °C with 1200 rpm and a contact pressure of 2574 Mpa for 60 min. Chrome alloy steel balls with 12.7 mm diameter having a Rockwell hardness of 61 were used for the experiments. The test balls and ball pot were cleaned by acetone and hexane after each run.

3. Results and discussions

The fatty acid composition of rice bran oil along with sunflower oil and coconut oil (Jayadas, 2008) are listed in Table 1. Rice bran consists of 24% saturated fatty acids, 41.86% mono unsaturated fatty acids and 30.99% poly unsaturated fatty acids. It has been reported