Analysis of the Effect of TBHQ and BHT Additives on Oxidation of Castor Oil

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Abstract. Global demand for industrial lubricants is increasing every year in line with the increasing of production and demand of various products. Castor oil has been acknowledged as one of vegetable oil base lubricant source that has advantages over mineral based lubricants due to their renewability properties. However, the use of this oil as industrial for long period of time is considered limited due to its tendency to oxidation which may lead to formation of deposition and varnish. Butylated hydroxytoluene (BHT) and tert-Butylhydroquinone (tBHQ) are typical additives added to various food grade vegetable oils and animal fats to enhance their preservation time. This research is carried out to: (i) examine the oxidation prevention properties BHT and tBHQ additives to castor oil due to high temperature, (ii) examine the effect of BHT and tBHQ loading to viscosity index of castor oil. Commercially available Castor oil was employed as base oil. The oil was loaded with 2.5–10 wt.% of BHT and tBHQ additives respectively. The oxidation of the oil was examined by adopting IP-48 standard testing. In this test, air was bubbled at 15 l/h of flow rate during a period of 6 h throughout 40 ml of oil sample at 150 °C. The oxidation prevention effect was determined from viscosity changes of the oil before and after testing at two temperatures of 40 °C and 100 °C respectively. The viscosity test was in accordance with the ASTM D445 and the viscosity index was calculated by ASTM D2270 standard method. The results shows BHT additive has better oxidation prevention compared to tBHQ additive. Optimum BHT loading is found at 2.5 wt.% and optimum tBHQ loading is at 5 wt.%. Oxidation process was found to have reduced the VI value although not so significant.

Keywords: Castor Oil · vegetable oil · Oxidation Stability

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1 Introduction

Lubricant typically applied on mechanical components to protect them from wear, corrosion, etc. Due to concern on depletion of mineral oil resources, application of naturally available oil has been considered [1]. Petroleum based oil basically can be replaced with vegetable oil by performing further physical and chemical properties modification and enhancement. Several researchers have put their interest in using vegetable oil and animal fat for lubricating purposes in recent years [2–5]. Compared to mineral base oil, vegetable oil base lubricant shall have several advantages such as good lubricating properties, high viscosity index, and low evaporation loses. However, vegetable oils typically have some drawbacks due to low thermal stability and oxidative stability. The resistance of typical natural plant oils to oxidation and thermal degradation is considered affected by the fatty acid contained in the oil [1, 6]. It is known that the fatty acid alkyl chain contained in most plant seed oil is susceptible to oxidation both at double bonds and adjacent allylic carbons [7, 8]. In addition, non-edible properties of castor oil do not affect demand for edible vegetable oils such as palm oil, coconut oil, etc.

Oxidation is a certain process happened in lubricating substance. This process directly started whenever the lubricant made contact with air and light (autoxidation) [8]. Various parameter such as elevated temperature, UV light, and presence of water and metals, can accelerated the oxidation process of lubricant oil. As result, increasing of viscosity, increasing acid number, degradation of properties enhancing additives, etc. can be occurs to the lubricants. Oxidation stability is a useful property in maintaining lubricant condition. Poor oxidative stability can lead to several consequences such as difficulties to flow which reducing friction and wear protection, corrosion of metal components, and formation of varnish.

Castor oil utilization as lubricant has its own advantages over other vegetable oil due to its better oxidation resistance than any other vegetable oils. This related to low content of unsaturated hydrocarbon in chemical structure of castor oil. Castor oil is mainly composed of 88–90% ricinoleic acid, 4.2–4.7% linoleic, and ±0.5% linolenic acids [9]. However, attention must still be given due to their natural tendency to rapid oxidation especially at elevated temperature. Therefore, this research is carried out to: (i) examine the oxidation prevention properties BHT and tBHQ additives to castor oil due to high temperature, (ii) examine the effect of BHT and tBHQ loading to viscosity index of castor oil.

2 Materials and Method

Commercially available castor oil was employed as base oil. Butylated hydroxytoluene (BHT) and tert-Butylhydroquinone (tBHQ) additives were obtained from Merck, Sdn. Bhd. These chemicals were typical compounds added to several food products to enhance the storage time of food products. Prior to oxidation test, the additive was loaded into base oil at different percentage in the range of 1–10 wt.% and mixed at room temperature by a magnetic stirrer device.

The oxidation test was performed by bubbling of air method adopting “IP 48: Determination of oxidation characteristics of lubricating oil” standard method. The schematic

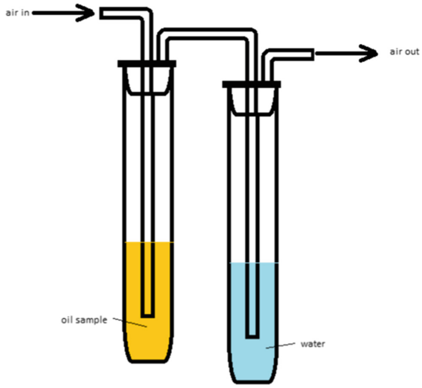

Fig. 1. Oxidation test Experimental set up

diagram of the experimental set up is shown in Fig. 1. In this test, air was bubbled at 15 l/h of flow rate during a period of 6 h throughout 40 ml of oil sample at 150 °C. The effect of oxidation was determined from the changes of viscosity before and after test which evaluated at two temperatures of 40 °C and 100 °C respectively.

The viscosity test was performed by using capillary viscometer in accordance with the "ASTM D445: Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)". The viscosity was evaluated at 40 °C and 100 °C and the viscosity index was determined by following "ASTM D2270: Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 °C and 100 °C".

3 Results and Discussion

3.1 Effects of BHT on Oxidation

Effect BHT additive loading to the castor oil can be seen in Fig. 2. The BHT additive clearly able to reduce the effect of oxidation based on the loading value. Significant effect observed at 2.5 wt.% of BHT loading for both viscosity testing temperature. However, it is concluded that the 2.5 wt.% loading is the optimum value for BHT loading into castor oil sample. Figure 3 shows the effect of BHT loading to viscosity index (VI) of the sample before and after oxidized. Viscosity index is a parameter that show stability of lubricant to flow at various working temperature. The higher VI value, the better stability of lubricant to flow at various working temperature. The VI value of castor oil sample is considered as high if compared to synthetic lubricant base [10, 11]. High viscosity index is one of advantages of castor oil application for industrial machinery. In this case, if there is operational temperature rises, the viscosity value of the oil is still maintained so the oil still easily flows from low temperature point to high temperatures point. It is observed that more than 5 wt.% BHT loading has negative effect on VI value to the non-oxidized castor oil samples. Oxidation process is found to reduce the VI value but insignificant. In addition, similar negative effect of more than 5 wt.% BHT loading to oxidized sample also observed.

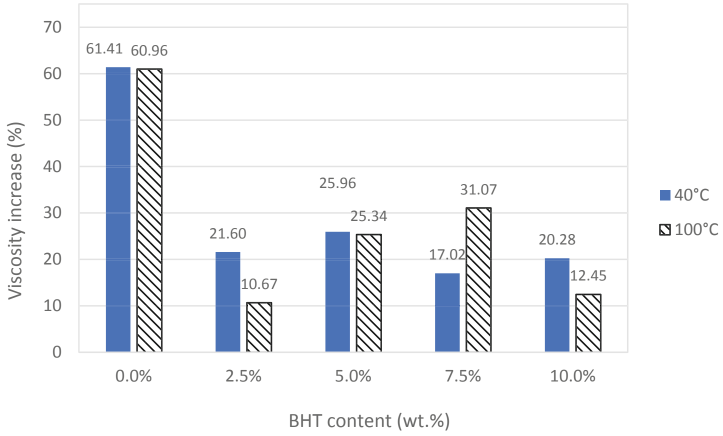

Fig. 2. Effect of BHT loading to oxidation of castor oil sample at viscosity testing temperature of 40 °C and 100 °C.

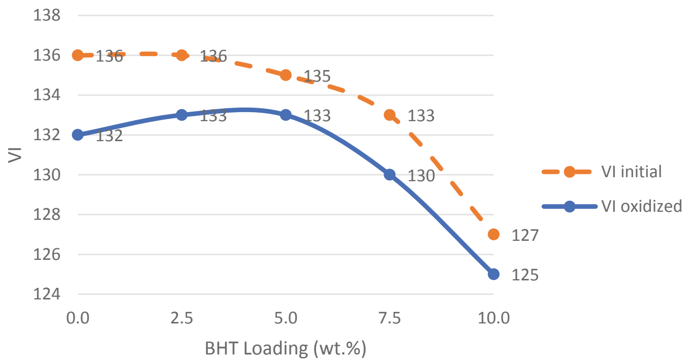

Fig. 3. Effect of BHT loading to viscosity indices (VI) of castor oil samples.

3.2 Effects of tBHQ on Oxidation

Figure 4 shown the effect of tBHQ additive to the viscosity changes of castor oil due to oxidation of evaluated at 40 °C and 100 °C respectively. Significant effect of oxidation prevention by tBHQ loading observed at more than 5 wt.% loading for both viscosity testing temperature. It is concluded that optimum value of tBHQ loading to improve oxidation prevention is at 5 wt.% loading. Figure 5 shows the effect of tBHQ loading to viscosity index (VI) before and after oxidized. Oxidation process is found to have reduced the VI value although not so significant. Similar trend to BHT, more than 5 wt.% tBHQ loading has negative effect on VI value for both oxidized and non-oxidized castor oil samples. These results suggest that BHT additive has better oxidation prevention compared to tBHQ additive.

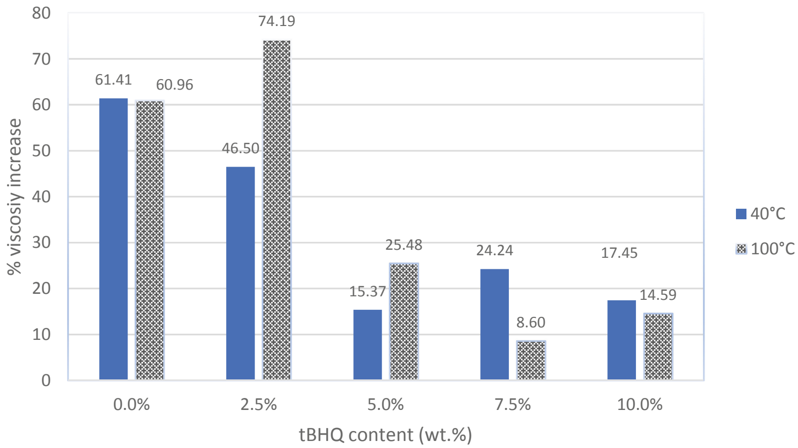

Fig. 4. Graph of Viscosity Results at a Temperature of 100 ºC.

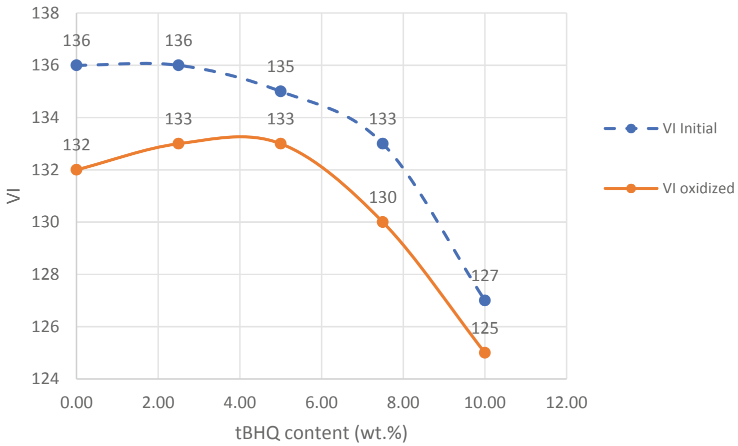

Fig. 5. Graph of Castor Oil Viscosity Index Results for BHT Additives

4 Conclusion

Based on the observation, we conclude that BHT additive has better oxidation prevention compared to tBHQ additive. Optimum BHT loading is found at 2.5 wt.% and optimum tBHQ loading is at 5 wt.%. Oxidation process is found to have reduced the VI value although not so significant. It is also concluded that more than 5 wt.% tBHQ and BHT loading into castor oil has negative effect on VI value.

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