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UTILIZATION OF *PONGAMIA GLABRA* SEED OIL IN THE DEVELOPMENT OF ECO-FRIENDLY PRODUCTS : AN OVERVIEW

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Efforts have been made to search eco-friendly specialty chemicals from spectrum of natural renewable resources. Among different renewable resources vegetable oils obtained from various seeds spotted largely due to their unique properties and eco-friendly characteristics. *Pongamia glabra* seed oil categorized as non-edible and abundantly available in the spectrum of nature. In present article effort has been made to overview the use of *Pongamia glabra* seed oil as an alternative fuel and feedstock for many polymeric recipes of viable applications. The uses of *Pongamia glabra* seed oil not only increase the feed stocks of eco-friendly renewable resources but also minimize the demand of petrochemicals going to deplete day by day.

KEYWORDS : Biodiesel, Biopolymer, Pongamia glabra, Renewable resource, Seed oil.

INTRODUCTION

The interest in the industrial use of oils from animal and plants stock is increasing significantly due to threat of global environment crises and the reduction in reserve and oil production volume (Samarth and Mahnwar, 2015; Alam and Alandis, 2011; Bisht *et al*., 1989). Development of eco-friendly products using materials obtained from renewable natural resources have gain considerable attention now-a-days throughout the world. Such developments not only reduce the emission of green house gasses but also provide an infinite alternative to the chemical industries as they have ability to grow again and again (Lebarbe *et al*,. 2012; Saremi *et al*., 2012). Renewable resources obtained from the mother nature's are successfully used for the development of useful materials as well as alternative fuels (Sharmin *et al.,* 2015; Kumar *et al*., 2003). Numerous renewable resources such as starch, lignin, protein, alginate, wool fiber and vegetable oil has been utilized in the formulation of various valuable materials of enormous utility in daily life (Lochab *et al.,* 2012*; Meier et al.,* 2007*; Bordoloi et al.,* 2015*)*. Among different renewable resources vegetable oils, a triglyceride embedded with different unsaturated and saturated fatty acids play vital role in the synthesis of specialty materials of practical utility in addition their application as biodiesel directly or with certain modifications (Guner *et al.,* 2006; Johari *et al.,* 2015). Seed oils are eco-friendly, biodegradable and abundantly available throughout the world at cheaper cost. Furthermore, use of non-edible vegetable oils in the different industrial applications provides a more fruitful utilization of renewable resource without affecting the stock of food materials (Islam *et al.,* 2014).

Pongamia glabra (Syn. Pongamia pinnanta) belongs to family Leguminosae is a shady and medium sized glabrous tree grows in the littoral regions of south eastern Asia and Australia (Sangwan *et al.,* 2010; Ahmad *et al.,* 2003). In India, it is mainly found in coastal areas, tidal forest land, river banks, sides of roads and railway tracks (Ahmad *et al.*, 2003; Ambastha, 1994). It can easily cultivate from seeds. Due to dense network of lateral roots, *Pongamia glabra* is known for controlling soil erosion and binding sand dunes. Different parts of the plants like leaves, bark, flower and seed have reported for the treatment of tumors, piles, skin diseases, wounds and ulcers. *Pongamia glabra* is also used for its anti-inflammatory, anti-plasmodial, anti-hyperglycemic, anti-diarrhoeal, antiulcer and antioxidant activity (Tanaka *et al.*, 1992; Chopade *et al*., 2008). *Pongamia glabra* tree yielded non-edible fruit. Its seeds contain about 30-40% oil embedded with both saturated and unsaturated fatty acids. In present article efforts has been made to overview the usage of *Pongamia glabra* seed oil in different industrial arena as well its utility as a biodiesel.

PHYSIC-CHEMICAL PROPERTIES AND COMPOSITION

The *Pongamia glabra* yielded non-edible seeds twice in a year which contain about 30-40% triglyceride oil. The thick viscous reddish brown oil is commonly known as pongan oil or pongmol oil (Sangwan *et al.,* 2010; Ahmad *et al.,* 2003). The physic-chemical properties and fatty acid composition of the vegetable oil varies slightly according to climatic conditions, nature of soil and purification methods (Solladie-Cavollo *et al.*, 2003). Monounsaturated oleic acid is the major constituting fatty acid (about 45-71%) of the oil. The degree of unsaturation of oil is directly related to its iodine value (about 80 g of I_2/100 g). On the basis of iodine value *Pongamia glabra* seed oil is classified as non-drying. The general structure of *Pongamia glabra* seed oil and major fatty acid constituents are depicted in Figure 1.

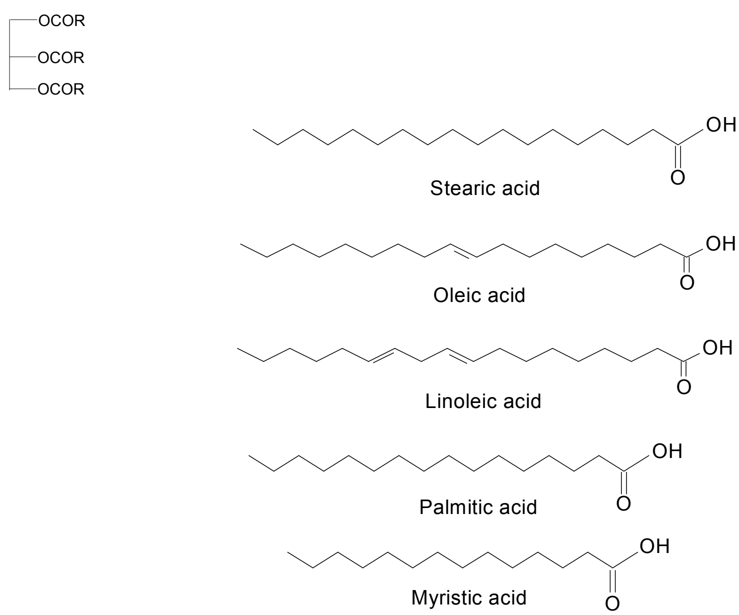

Fig. 1. General Structure of vegetable oil and common fatty acids

Biodiesel

The search for alternative and sustainable resource for petrochemical has become significant now-a-days, due to fast depletion of petrochemical stock and fluctuation in prices. Vegetable oils obtained from different plants have got the prominent attention of academician and technologist to develop as an alternative fuel (Kumar *et al*., 2003; Freedman *et al*., 1986; Dornoko and Cheryan, 2000; Monisha *et al*., 2013). This is reasonably, due to its unique properties like easy availability, renewability, friendly to the environment and furthermore, their production can be increased by more plantations when ever required.

Pongamia glabra seed oil is categorized a as non-edible oil and directly used by the farmers as fuel to run the water pumps that irrigate their field (Kamree *et al*., 2004). However, like other triglyceride oils, there are limitations in the use of this non-edible oil as fuel like as its high viscosity, poor atomization, fuel injector blockage, excessive engine deposit and engine contaminations. Products obtained after trans esterificaion of vegetable oils commonly known as a biodiesel and known for the improved performances in terms of fuel over the normal vegetable oil. Biodiesel fuel can be defined as medium chain length mono alkyl fatty acid ester (Kumar *et al*., 2003; Sangwan *et al.,* 2010). Such transformation of *Pogamia* oil also improves its fuel characteristics remarkably (Freedman *et al*., 1986). The transestrification can be performed by the reaction of triglyceride oil with an excess of alcohol (mainly methanol) in presence of acid or base as a catalyst. Base catalyzed transesterification generally preferred due to faster rate of conversion (Sridharan and Mathai, 1974). Common catalysts used for transesterification are NaOH, KOH or alkoxides. Among them utilization of KOH is more fruitful as neutralization of reaction mixture with phosphoric acid on completion of reaction yielded potassium phosphate, a well known fertilizer (Kamree *et al*., 2004). Transesterification reactions are reversible in nature and hence it is required to use either a large excess of alcohol or remove the one of the product to shift the equilibrium towards forward direction. A molar ratio of 6:1 is normally used for industrial processes to obtain methyl ester (Kumar *et al*., 2003). Kinetic study of the base catalyzed transestrification of monoglyceride of *Pongamia* oil was carried out by Karmee *et al, 2004*. ^{1}HNMR spectroscopy was to monitor the progress of transestrification reaction. The forward rate constant was increased with an increased in temperature, where as the reverse rate constant showed to decreasing trend (Kamree *et al*., 2004). *Pongamia glabra* is known for its multipurpose benefits and as a potential source of biodiesel (Sangwan *et al*., 2010; Kamree *et al*., 2004). It has been reported that cetane value of biodiesel derived from pongamia pinnata oil is 51.0 comparable to cetane value of diesel which is 47.8 (Sangwan *et al*., 2010). Furthermore, biodiesel of Pangomia glabra seed oil claimed for comparatively negligible corrosion on different parts of engine with respect to diesel. Corrosion characteristics of fuel are an important parameter for long term durability of engine (Kaul *et al*. 2007).

Syntheses of Bio-Polymers

The use of vegetable oil in general and non-edible in particular in the syntheses of monomer, polymers and other specialty chemicals reduces the dependency on petrochemical as well as minimizes the environmental problems (Guner *et al*., 2006; Johari *et al*., 2015; Sharma and Kundu, 2006; Belgacem and Gandini, 2008; Ahamad *et al*., 2016). These polymeric and oleochemical materials are eco-friendly and biocompatible and are degradable after a certain time (Meier *et al*., 2007; Petrovic, 2010).

Pongamia glabra seed oil (PGSO) is reported to use a precursor of natural renewable resource for the syntheses of polymeric materials of practicable utilities. PGSO chemically triglyceride react with diethanolamine in presence of sodium alkoxide and produces *Pongamia glabra fattyamide diol*. The fatty-amide diol contain hydroxyl groups on the both terminals in addition to a pendant amide linkage and behaves as monomer for many polymeric recipes (Ahmad *et al*., 2003).

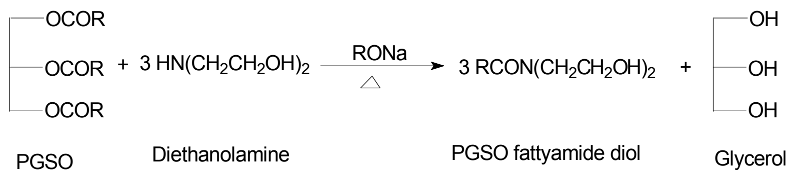

Fig. 2: Reaction Scheme for PGSO fattyamide diol

Poly (ester-amide) of PGSO was obtained by the poly (condensation) reaction between fatty amide diol (a diol) and phthalic acid (a dicarboxylic acid). In order to facilitate the reaction in forward direction byproduct water was removed using Dean-stark trap during the poly (condensation) reaction (Ahmad *et al.*, 2003). The resulting polymers contain both pendant amide group and repeating ester linkages and reported as a useful material for corrosion protective coatings. They also claimed that monomer and polymer both are inert and biologically safe for the use of human population (Ahmad *et al.*, 2003). In order to improve the physic-mechanical and protective efficiency as well as reduction in curing temperature and time, aluminium was incorporated in the *Pongamia glabra* poly (ester-amide). The resulting polymer was reported for significantly improved physic-mechanical and corrosion resistance properties with notable decrease in curing temperature (Ahmad *et al.*, 2006).

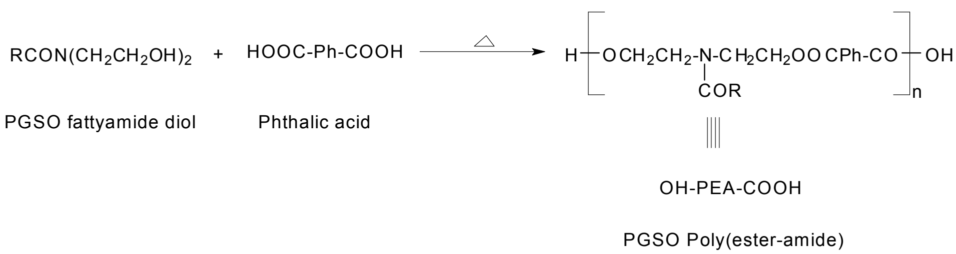

Fig. 3. Reaction Scheme for PGSO Poly(ester-amide)

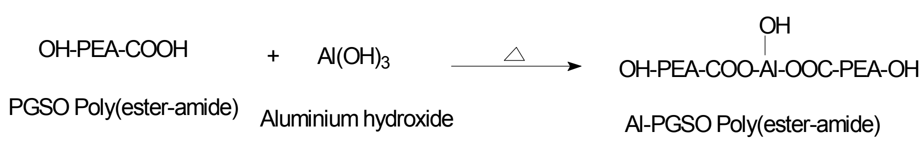

Fig. 4. Reaction Scheme for Al-PGSO Poly (ester-amide)

Curing at elevated temperature is a multistep and energy consuming process, furthermore it restrict the application where baking are not possible. To solve these problems efforts was made to design self cured poly (ester-amide) of *Pogamia glabra* seed oil. Fatty amide diol of PGSO was reacted with poly (styrene-co-maleic anhydride) (SMA) copolymer. The resulting polymer was further reacted with phthalic anhydride in different ratios in view to investigate the optimum amount on the basis of film properties (Zafar *et al.*, 2008). They also explained the curing mechanism by taking the FTIR spectra of resin before and after curing. The study provides more viable utilization of *pongamia glabra* seed oil.

Pongamia glabra seed oil reported to use a precursor in the synthesis of poly(urethane-fatty amide) using a one-shot technique (Kashif *et al.*, 2010). The fatty amide diol of PGSO was reacted with tolylene-2,4-diisocyanate (TDI) in different ratios in presence small amount of organic solvent (8-10%). The resulting polymer was reported to cure at room temperature within the very short time. Curing mechanism was investigated by taking the FTIR spectra of the uncured and cured resin.

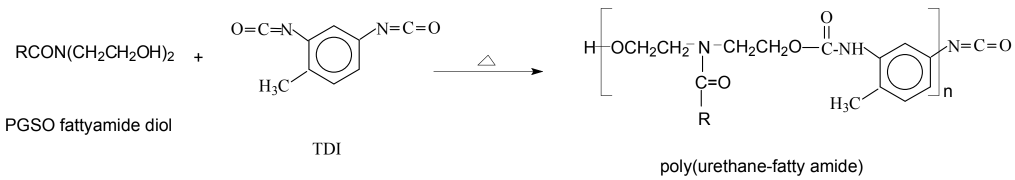

Fig. 5. Reaction Scheme for Poly(urethane-fatty amide)

The resulting polymer was claimed for synergistic properties of both urethane and amide linkage. It has been reported that polyurethane of PGSO shows good physic-mechanical properties, excellent chemical/corrosion resistance and moderate antibacterial performances (Kashif *et al.*, 2010). The poly(urethane-fatty amide) also claimed for the good performances in alkaline medium due to absence of soponifiable ester linkages.

Conclusion and prospects

IIn this article efforts have been made to provide an overview of physic-chemical properties and utilization of *Pongamia glabra* seed oil as a fuel as well as a renewable feed-stock for many environment friendly polymer recipes. The manuscript provides an insight of *Pongamia glabra* seed oil as a potential candidate for the development of environment friendly materials. It yielded value added materials by simple chemical reactions, which find copious applications, especially as corrosion protective coatings. The utilization of *Pongamia glabra* seed oil in different value added materials with less hazardous impact on environment, cut down the demand of petrochemicals as well as reduce the pressure on the other triglyceride oils, among them some are edible too. Thus the use of *Pongamia glabra* seed oil categorized as non edible, heaping up the feed stocks, a move towards ultimate goal of sustainable development.

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