Materials Today: Proceedings 44 (2021) 3583–3588

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Investigation on the lubricating behavior of cashew nut shell liquid oil as a renewable and reliable petrochemical product

M. Selvamuthukumar [a,*], B. Harish babu [a], Sujith bobba [a], S. Baskar [b], Nivin Joy [c]

[a] Department of Applied Engineering, Vignan's Foundation for Science, Technology and Research, Guntur -Tenali Rd, Vadlamudi, Andhra Pradesh 522213, India
[b] Department of Automobile Engineering, Vels Institute of Science, Technology and Advanced Studies (VISTAS), Chennai, Tamilnadu, India
[c] Department of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, Tamilnadu, India

ARTICLE INFO

Article history:
Received 30 August 2020
Received in revised form 12 September 2020
Accepted 16 September 2020
Available online 28 October 2020

Keywords:
Cashew nut shell liquid
Cardanol
Base lubricant
Lubricating behavior
Pyrolysis process

ABSTRACT

In order to compact the ecological and harmful concerns of lubricants, it is necessary to focus on the environment-friendly oils as lubricants and manufacturing. Aforementioned studies reveal the significance of Cashew Nut Shell Liquid oil as renewable, biodegradable and non-toxic to the environment, hence the current study sought to explore the lubrication property of Cashew Nut Shell Liquid oil (CNSL) in comparison with base lubricant oil (SAE 20 W-40). In order to improve the lubrication in internal combustion engines, the study is conducted with various blends and the properties are evaluated as per ASTM standards. We believe ours is the first report to study the lubricating behavior of cashew nut shell liquid oil before and after pyrolysis process. Our study focuses on testing the CNSL oil according to the ASTM test standard and proposing the optimized blend for improving lubrication in IC engine by 8%.

Selection and peer-review under responsibility of the scientific committee of the 3rd International Conference on Frontiers in Automobile & Mechanical Engineering.

1. Introduction

Lubricants serve as a barrier against friction. They make it easy to run efficiently, keep system operations consistent and reduce the possibility of repeated errors. Currently, rising fuel oil costs, exhaustion of world crude oil supplies and global environmental awareness have reinvigorated the growth and use of renewable lubricants from substitutes. A bio lubricant is a biodegradable, non-toxic recycled lubricant that contains net-zero greenhouse gases. Owing to their low toxicity, decent lubrication, high viscosity index, high combustion temperature, the improved lifespan of devices, good wear characteristics, good friction coefficient, normal multi-grade properties, a low evaporation rate and low pollution in the atmosphere, biologic compounds are potentially alternative lubricants. Biosynthetic is a possible alternative lubricant [1]. The renewed interest is in the production and usage of alternate lubricants owing to the rising oil prices, the decline of the global oil reserve and the need for protection against contamination by lubricating oils and they are uncontrolled depilate. Bio lubricant oils have some natural technical features and are biodegraded, and so are known as substitutes for mineral oils. Vegetable oil-based bio-lubricants typically have a high lubricity, high viscosity ratio , high flash points, and low evaporative losses relative to mineral oils [2,3].

Nagendramma et al. [4] has researched the production of environmentally friendly biodegradable lubricants and have found that synthetic and vegetable oil-based esters provide the best selections in the formulation of environmentally safe lubricants for motor transmission fluids, cold rolling oiled products, metal-working fluids and fireproof hydraulic fluids. The chemical modification of deoxidized oleic acid was used to manufacture Synthetic bio lubricating base stocks with increased low temperature and oxidative stability. Double bond elimination from acyl acid group fatty acid, raise in viscosity and the durability in the oxidation of the substance is due to the molar weight and improvements in molecular structural conditions [5]. Vegetable oils are the most commonly used feedstock for bio lubrication since they are organic and have a high consistency of a finished product such as an acceptable index of viscosity, strong pour rate, and an effective loss of vaporization [6]. The thermodynamic constant of the phase specifies the

* Corresponding author.
E-mail address: m.selvamuthukumar@gmail.com (M. Selvamuthukumar).

https://doi.org/10.1016/j.matpr.2020.09.458
2214-7853/
Selection and peer-review under responsibility of the scientific committee of the 3rd International Conference on Frontiers in Automobile & Mechanical Engineering.

production in an esterification reaction. There is not, as is the case for transesterification, the absolute transient yield based on the enzyme domain. When the catalyst is esterified, it simply increases the reaction rate and when the production is changed whether the enzyme is affected, the inactivation or inhibition of the enzyme is the result [7]. Automotive oils and lubricants provide a most probable option for the production of sustainable and environmentally safe lubricants in response to increased environmental concern. The versatility of vegetable oils in terms of environmental costs gives them an advantage over traditional mineral oils [8]. Many researchers improved engine applications with various methods [9–11]. These studies reveal the significance of Cashew Nut Shell Liquid oil as renewable, biodegradable and non-toxic to the environment, hence the current study sought to explore the lubrication property of Cardanol oil (C) obtained by the pyrolysis from Cashew Nut Shell Liquid oil blended with the base lubricant oil (L) with a grade of SAE 20 W-40. The properties study were conducted with various blends from 10% to 40% of CNSL with base lubricant.

2. Pyrolysis of Cashew nut shell oil

Pyrolysis generally defined as thermal decomposition of organic materials in the absence of oxygen at a temperature range of 400–650 °C to produce char, tar and gas. The pyrolysis pathway is illustrated in Fig. 1. The conversion of biomass into liquid may be either

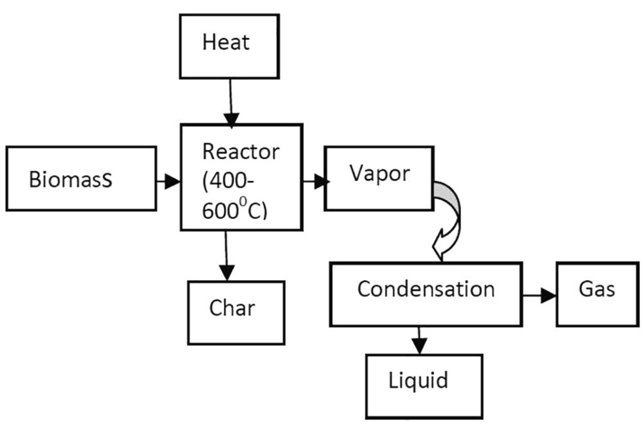

Fig. 1. Graphical view of pyrolysis pathway.

Table 1
Composition of CNSL oil before and after pyrolysis process.

Before pyrolysis (Natural CNSL)	After pyrolysis (Technical CNSL)
• Anacardic acid 71.65%	• Cardanol82-84%
• Cardol 23.98%	• Cardol8-11%
• Cardanol5.10%	• 2-Methylcardol1-3%
• 2-Methylcardol1.10%	• Polymeric material8%'

by a fixed bed or fluidized bed pyrolysis system. Fixed bed pyrolysis method may be considered as a promising option where feedstock feed and heat is supplied externally. Nitrogen gas is used as an inert gas to make an inert environment in the reactor. Biomass which is Cashew nutshells are fed to the reactor from outside and the heat is supplied to the reactor uniformly.

The fixed bed reactor is heated to the temperature of 400-600° C and the nitrogen gas is supplied to the reactor at the desired flow rate which makes the reactor environmentally inert. Vapour residence time is an important parameter to achieve maximum yield. Due to high temperature inside the reactor vapours comes out of the reactor and it is cooled rapidly with the help of condenser. The water-cooled counter flow condenser is used. Rapid cooling of pyrolysis vapour influences on maximum product yield. The liquid is collected separately and the non-condensable gases are flared into the atmosphere. The liquid, solid char and gas is the product obtained by pyrolysis process. The CNSL obtained here is Technical CNSL. As the extraction method varies the quantity and then the quality of oil varies with the composition of the oil. The composition and properties of CNSL oil before and after pyrolysis process are analyzed and summarized in Table 1 and Table 2.

3. Performance characteristics

3.1. Density

Density is the key property for the lubricants. This value is used for some calculations such as viscosity so it has to be evaluated. From Fig. 2 it is observed that the density of cardanol oil is very high when compared to conventional lubricant (SAE20W-40). Thus we conclude that if we increase the cardanol oil %, density increases for all the blends. With this property along with the viscosity, we can judge the lube oil performance.

3.2. Aniline point

It is defined as the minimum temperature at which equal volumes of hydrocarbon oils and aniline gets separated in two phases". This value indicates the structure of mineral oils. From Fig. 3 it is observed that based lubricant has a higher temperature when compared to all blends. This is because mineral oil has the majority of paraffinic content which is desirable for lubrication i.e.; higher the temperature of separation; more the paraffin content. It is observed that "90%L + 10%C" have an aniline point of 49 °C closer to the base lubricant of about 54 °C.

3.3. Oxidation stability

Oxidation is a very important form of chemical breakdown of motor oil and its additives. The chemicals that are present in the motor oil will react continuously with oxygen that is inside the engine. The effects of the oxidation due to this reaction as well as the by-products of combustion produce very acidic compounds

Table 2
Properties of CNSL oil before and after pyrolysis process.

Properties	Before pyrolysis(Natural CNSL)	After pyrolysis(Technical CNSL)	Results
pH value @ 25 °C	3.5	6.1	Changed fromacidic to basic
Specific gravity @ 25 °C	1.007	0.920	Lowered
Kinematic Viscosity@40 °C and @80 °C	47.513 cStand9.398 cSt	22.19 cStand3.93 cSt	Lowered
IV in (mg iodine/100 g of fat)	218	267	Increased
Carbon residue in (%)	5.32%	0.92%	Lowered
Ash content in (%)	5.61%	1.03%	Lowered

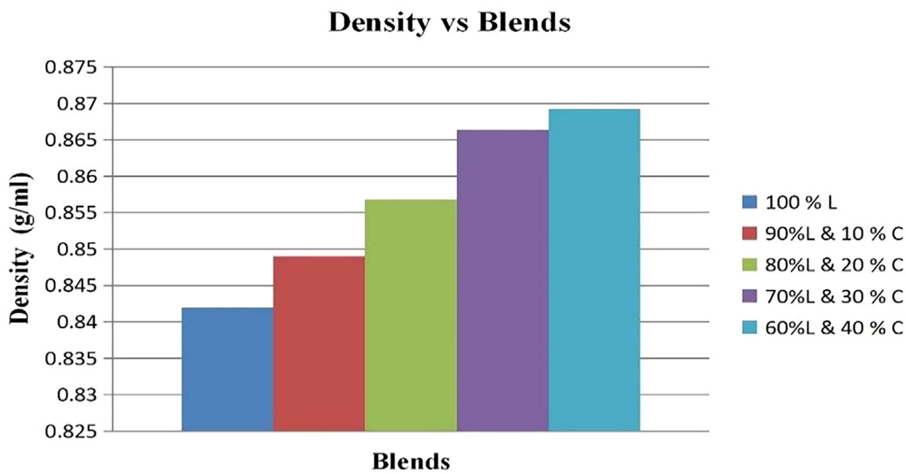

Fig. 2. Comparison of density for various blends of cardanol and mineral oil.

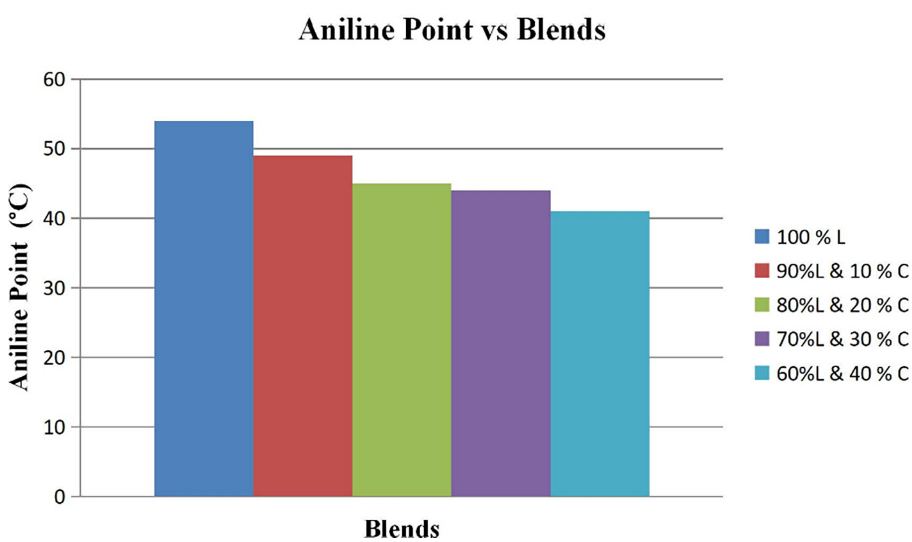

Fig. 3. Comparison of aniline point for various blends of cardanol & mineral oil.

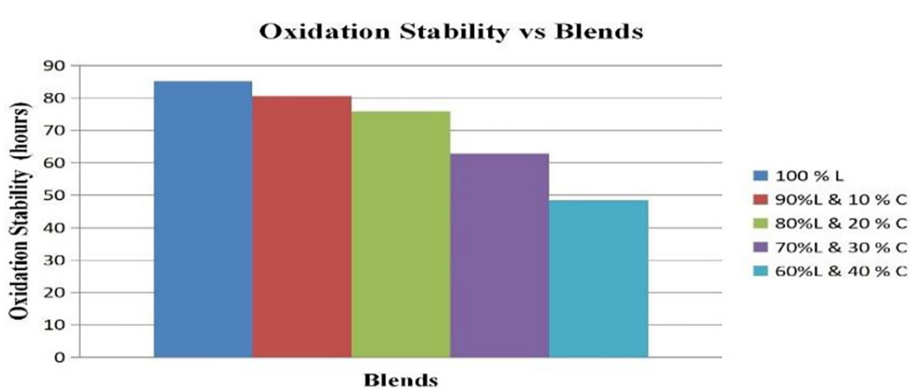

Fig. 4. Comparison of oxidation stability for various blends of cardanol & mineral oil.

inside the engine so it is important to determine the oxidation stability of engine lube oil. From Fig. 4, it is observed that the base lubricant have higher values when compared to all the blends. This is because, the vegetable-based oils present in their natural form lacks the stability of oxidation i.e. the oil that is oxidized rapidly during use, becomes thick or hardened and thus polymerizing to plastic-like tendency. This can be avoided by chemical modification of vegetable-based oils or by using additives or by blending with mineral oil because mineral oils contain additives to suppress the oxidation. It is observed that "90%L + 10%C" have oxidation stability of 80.56 h which is closer to that of base lube oil about 85.22 h.

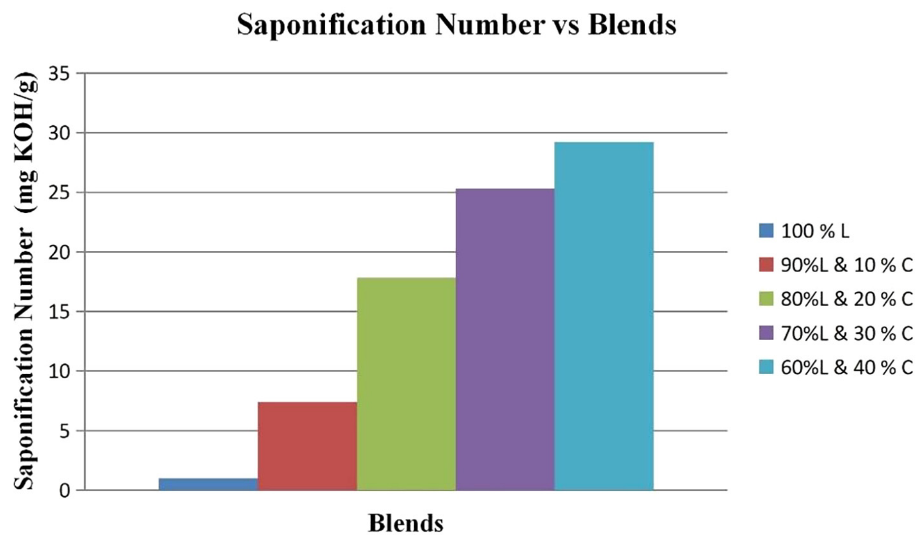

Fig. 5. Graph of saponification number for various blends of cardanol & mineral oil.

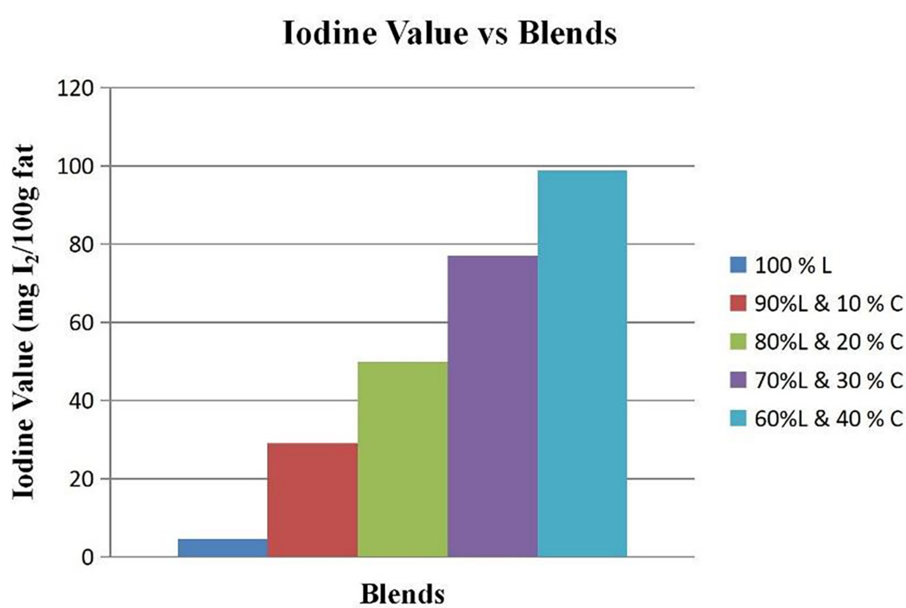

Fig. 6. Comparison of iodine value for various blends of cardanol & mineral oil.

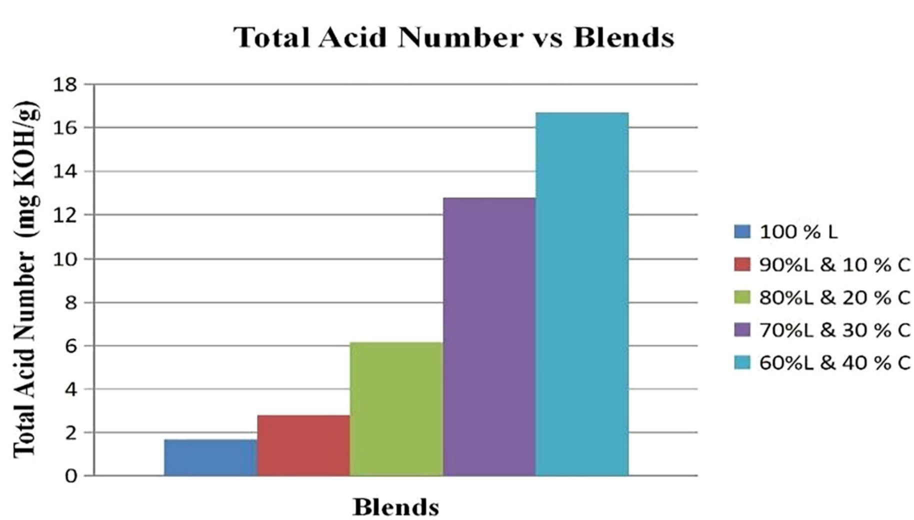

Fig. 7. Comparison of total acid number for various blends.

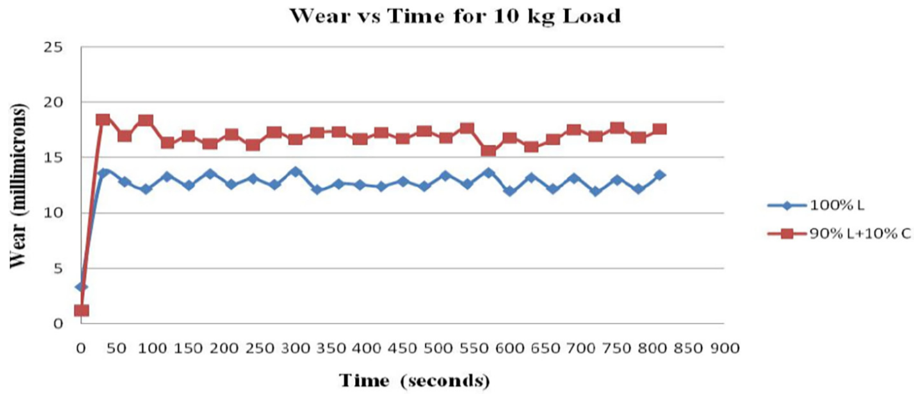

Fig. 8. Comparison of wear test for optimised blends & 100% base oil at 10 kg load.

Table 3
Wear study parameters.

Parameters	Value
Diameter of Pin	12 mm
Disc Diameter	100 mm
Sliding Velocity	3.78 m/sec
Speed	700 rpm
Time	13.30 mins
Load	50 N, 100 N, 150 N

3.4. Quality characteristics

3.4.1. Saponification number

Saponification number is defined usually as the amount of mg of potassium hydroxide required to saponify 1 gm of oil or fat i.e. to neutralise completely the fatty acids resulting from complete hydrolysis of 1 gm fat or oil. From Fig. 5, it is observed that saponification number goes on increasing when the percentage of cardanol increases. This is due to the presence of "Saponin content" present in cardanol. This is undesirable as it leads to the formation of soaps. This can be minimised either by adding anti-foam additives or simply blended with the mineral oil. It is also observed that "90%L + 10%C" has a saponification value of 7.41 mg of KOH/g of fat when compared to that of base lube oil which has the value of 1 mg of KOH/g.

3.4.2. Iodine value

Iodine value is the number of grams of halogen that is absorbed by 100 g of the oil's fat, and it is expressed as the weight of iodine. It is a measure of its degree of unsaturation and gives us an idea about its drying character. The iodine value depends on the double bonds that are present in the molecules. From Fig. 6 it is observed that iodine value increases when the % of cardanol increases. This is due to the presence of unsaturation (i.e. no of double bonds) present in cardanol when compared to mineral oil (majority is paraffinic nature). It can be overcome by simply blending with the base lube oil. It is also observed that "90%L + 10%C" have an iodine value of 29.14 mg iodine/100 g fat when compared to base lube oil which has the value of 4.65 mg iodine/100 g fat.

3.4.3. Total acid number

The Total Acid Number is the weight in mg of potassium hydroxide that is required to neutralize 1 g of oil. It is used as a guide in the quality control of lubricating oils. The acid concentration of a lubricant usually depends on the presence of additive package, acidic contamination and oxidation by-products. From Fig. 7, it is observed that based lube oil has the lowest value when compared to all other blends. This is due % of free fatty acids content present in cardanol. It is also observed that "90%L + 10%C" have acid value 2.805 mg of KOH/g of fat to that of base lube oil has value 1.683 mg of KOH/g of fat.

3.4.4. Wear study characteristics

The optimized blend "90%L + 10%C" is then studied for their wear behaviour in comparison with base lube oil. The wear test is performed on "Pin on Disc Tribometer" equipment according to standard test method "ASTM G 99" under the following conditions stated in Table 3.

It is observed that the wear rate for 100% lube is lower when compared to the optimized blend during the whole range of operation. It is also observed that the wear rate pattern remains the same for the entire duration of 850 s. Therefore, it is concluded that at medium load the wear rate will be higher for the optimized blend and it is not suitable for medium load applications.

3.4.5. Wear characteristics of lube oil blend at 10 kg load

From Fig. 8, it is observed that the wear rate for 100% lube is lower when compared to the optimised blend during the whole range of operation. It is also observed that the wear rate pattern remains the same for the entire duration of 850 s. Therefore, it is concluded that at medium load the wear rate will be higher for the optimized blend and it is not suitable for medium load applications.

4. Conclusion

Our study demonstrates the lubricant property of the Cashew Nut Shell Liquid oil in comparison with the base lubricant oil. The properties study were conducted with various blends from 10% to 40% of CNSL with base lubricant. In order to reduce the harmful concerns of synthetic lubricants, it is necessary to focus on the environment-friendly oils as lubricants and manufacturing. The CNSL oil is tested according to the ASTM test standard and an optimized is proposed for improving the lubrication in internal combustion engines by 8%. On the whole, it is concluded that by adding suitable additives such as Molybdenum disulphate (MoS_2), Viscosity Improvers in varying amount, percentage of Cardanol in the blend can be improved by another 20%.

CRediT authorship contribution statement

M. Selvamuthukumar: Conceptualization, Investigation, Methodology, Writing - review & editing. **B. Harish babu:** Resources, Software. **Sujith bobba:** Data curation, Formal analysis.

S. Baskar: Validation, Visualization, Writing - original draft. **Nivin Joy:** Project administration, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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