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Evaluation of Vegetable Oil-Sourced Lubricants for Transition to Green Alternative at Sustainable Energy Solutions for Automotive Industry

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Abstract

In recent decades, the rising energy needs has concluded in much more lubricant usage. Lubricants play a significant part in decreasing the friction and wear among bustling superficies. They are among the greatest drivers of oil need. The ecological affects arising from the direct petroleum-based lubricants' entry requires the implementation of bio-sourced lubricants as a perfect option to petroleum-derived lubricants. The bio-sourced lubricants' primary resources are oils derived from plants. There are numerous compatibilities between petroleum-based lubricants and triglycerides from the view point of physical and chemical features. Because of their non-food competition, less expense, and simple usability, vegetable-sourced oils are a potential option to fossil-sourced lubricants for the fabrication of wide-ranging sector implementations. Thus, the implementation of nonedible oils as a maintainable bio-based lubricant source plays an important part in lubricant sectors.

In this study, the physicochemical features, molecular structures, and other important lubrication efficiency parameters were researched which is necessary for vegetable oil-sourced lubricant choice. Within the industry standards, this study aims to found the most appropriate vegetable-sourced lubricant base on diverse characteristics present. A table of characteristics is evaluated. Finally, the criterion weighting methodology implemented to the emerging scheme. The implementation of the results from this study provides an opinion of how the criterion weighting modeling can be applied in vegetable oil-sourced lubricants.

1. Introduction

The ever-increasing development, modernization and industrialization have raised the need for power. It is anticipated that the global power usage will be raised about 34% until year 2030 [1]. Such an increase in energy usage is generally associated with petroleum-based energy resources. Further fossil-derived materials with the inclusion of lubricant and fuel are required to respond to the high demand for energy. Lubrication plays a significant part in continuous, financial, and correct moves [2]. The lubricants are vital in overall mechanic parts since they decrease the friction and wear of bustling systems through creating a proper oil film among the metal interfaces [3]. Thus the efficient lubrication is compulsory to diminish wear and heat commonly in mechanical implementations.

The hydraulic oils, compressor oils, transmission oils and metalworking fluids are some examples of widespread lubricants utilized in sector [4]. It is predicted that about 35,000,000 tons of lubricants are used yearly [5]. Almost 50 percent of overall mineral lubricants get in the ecology and this creates improvable harm to the ecology because of their direct touch with soil and water [6, 7]. About 95% of the lubricants that end up in the atmosphere are fossil-sourced, which is a serious concern for the environment [8]. Mineral oils contain acids that can affect a million liters of drinking water in just one kilogram [9].

This is an important point as numerous fossil-sourced lubricants are non-renewable and toxic. Improper disposal and continuous combustion of these materials are proved to be detrimental to nature in long-term. Numerous endeavors have been done to forestall the ecological contamination by environmental laws and diverse government directives. These has accepted some novel regulations and laws on the utilization of sustainable energy resources, containing lubricants and fuel manufacturing [10]. It has been already estimated that the minerals oil's continuous usage gives rise to the minerals oil's shortage in future [11]. To exceed the troubles many investigators have tested to substitute the petroleum-sourced and synthetically lubricants into the cost-effective, decomposable, and environmentally friendly lubricants. It is essential to utilize the lubricants having minimal reverse result on the environment for the improvement solidity [12]. Bio-sourced lubricants can be the options of the mineral oil-sourced lubricants due to their natural biodegradability and technic features. The investigations display that the

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vegetable-sourced oils are favorable as front material in production [13-15]. Also, as crosscheck with the mineral-based oils the vegetable oils' degradation ratio about 25% more and they are 95% bio-degradable [16, 17]. They have the lower volatility, bigger viscosity index, and bigger flash point. The vegetable oil's structure occurs with the polar classes and fatty acids long series because of this they occur proper for boundary and hydrodynamic lubrication in mechanic vehicles [18, 19]. The properties of vegetable-sourced oils are crosschecked with the fossil-based diesel fuel and the investigators are obtained that waste organic lubricant and the animal fats have better lubricity [20].

The world requires environmentally acceptable lubricating oils in order to achieve long-term development with a lower net negative impact on the environment [21]. In terms of economics, investing in bio-based lubricating oils is important for developing countries, particularly those where agriculture is the primary source of revenue. [22]. Vegetable oils are derived from the seeds and fruits of plants [23–25], and their primary applications include cosmetics, medicines and animal feed, and soaps [26]. They are biodegradable, non-toxic, and renewable [27], making them ideal feedstocks for bio- based lubricant formulation / production [28, 29].

In this study, the most feasible plant oil choosing problem is assessed among vegetable oil species as lubricant for automotive sector. The comparative assessment of thirteen diverse renewable vegetable oils is ensured. The purpose of this article is to choose the most feasible sustainable vegetable oil as lubricant through the use of criterion weighting modelling.

2. The primary properties of analyzed vegetable oil-sourced lubricants

The lubrication is described as the relative movement's facilitation of the superficies in touch with each of the others through lubricant materials. The lubricants are needed in all mechanic vehicles. Moving between the parts that are in touch with each of the others, lubricants decrease the friction and wear of heat-energy losses and moving parts, and expand the components' lifespan in mechanic vehicles [30, 31]

In an automotive implementation it is important to utilize the lubricants between the moving/contacting superficies. The mineral-sourced oil has been utilized greatly in automotive implementations as frictional detractive [32]. Lubricating oils are usually made up of base stocks that have been enhanced with additives to boost their features. Base stocks are used to incorporate additives because they have some pre-described features such as low oxidative stability and viscosity index, which are not appropriate for lubricating oils. The following are some of the base-stocks: The mineral-source base oils are derived from fossil-sourced products utilized in the refining of raw oil [33, 34]. Refined oil base-stocks obtained by extracting insoluble and volatile ingredients from refined fossil-sourced products [35]. Synthetic-based base oils can be made from fossil-sourced oil through modifying it chemically. Animals and plants are used as biomass base stocks in the bio lubricants' production, while agro-residues and vegetable oils are also used [36–38].

The bio-derived lubricants' improvement from plant oil sources is appealing to investigators as plant oils have broad orders of physical-chemical features. The plant oil occurs efficient because of its biodegradable, environmentally-friendly, and renewable. At excessive circumstance temperature, plant oil basis lubricants can resist. The biomass that contains oil is a maintainable option to mineral-based lubricants. The oil-bearing biomass's HC formations and mineral oil are greatly akin to each of the others. The biomass that contains oil is obtained in animal and plant oils, which are named triglyceride or tri-glycerol [39]. Bio-degradability and renewability are the maximum resistance of bio-sourced lubricants. They propose the most convenient resolution as replaces in feedback to the rising pollution exposure through recently utilized mineral-sourced lubricants. The mineral-based oils are toxic and non-renewable in terms of the effect to nature. The asset of fatty acids within plant oils has concluded in better lubricity and greater flash point upon crosschecked to mineral-based oils. At the same time, other features like viscosity, oxidative stability, and pour point of plant-based oils are mainly defined through the fatty acids' structure. Plant-based oils with high grade of saturation fatty acids have more preferable oxidative steadiness, good viscosity value but subnormal pour point, and vice versa. Restrictions of bio-sourced lubricants, primarily raw plant oils are named to have less temperature and less oxidative steadiness which restrict their whole potency for broad-scale consumption. Chemically alteration through diverse methodologies is encouraging alternatives for manufacturing bio-sourced lubricants from raw plant oils. These methodologies have been obtained to efficiently combat the defects of raw plant oils, generating final materials that surpass or meet norm needs. To functionalize the bio-sourced lubricant, numerous investigators crosschecked the velocity coefficient, physiochemical parameters and other characteristics of the mineral-based oils. The viscosity is the significant characteristic which designates the liquid strength to run at changing temperatures and make inferences on the film structure between moving and stationary superficies [40–42]. At 21^0C, fatty acids with unsaturation's greater degrees have lesser viscosity. Therefore, oils with high fatty acids monounsaturated have excellent lubricity at 21^0C [43]. An increment in HC-chain length also rises the viscosity because of increase in random interactions of intermolecular [44]. At elevated temperature, saturated plant oils have more preferable oxidative steadiness than unsaturated oils. While amongst unsaturated plant oils, monounsaturated plant oils have more preferable oxidative steadiness than polyunsaturated plant oils [45]. The plant oils with higher fatty acid unsaturated ingredients will have lesser pour point because of fatty acid bond in twisted style will avoid molecules' close packing at low temperatures [46]. The linear chained combinations' biodegradation seems to consist more than that of furcate combinations [47]. Thanks to their environmentally friendly nature, plant-based oils are useful for bio lubricants, despite the ever-raising cost of petroleum. Although it does not meet the requirements of petroleum-based lubricants, plant oils have high lubrication, flash point, and viscosity index, and less evaporative losses in terms of pre-described features [48-50]. Plant oil has been displayed in numerous studies to be a flawless agent for producing durable lubricants that meet the applications and requirements. Some popular bio-lubricant raw materials are listed below.

Castor beans are used to make castor oil. Castor oil's triglyceride includes ricinoleic fatty acid bonds (90 percent). It is a great lubricant for diesel, racing, and jet engines because of its high temperature lubricity and low temperature viscosity [51]. For cooking, soybean oil is the most commonly utilized alternative. Soybean oil's fatty acid formation also includes great share of mono unsaturated oleic acid (23 percent) and linoleic acid (51 percent). Soybean oil has been successfully tested as a transformer dielectric fluid because it has the potential to increase the transformer life and fire point through extending the insulating paper's life [52]. Sunflower oil is extracted from sunflower seeds. The sunflower oil is primarily a triglyceride which is constituted of linoleic acid (polyunsaturated), stearic acid (saturated), palmitic acid (saturated), and oleic acid (monounsaturated) [53]. Higholeic acid (82 percent oleic acid condensation) is considered to be the most proper fatty acid for lubricants due to its oxidation stability and high lubricity. In cold temperatures, sunflower oil has a higher viscosity because of its unsaturated fats' high level [54]. Rapeseed oil is primarily cultivated from its rich-oil seed that is high in Erucic acid (54 percent). Since rapeseed oil has more oil per unit land field in comparison to others plant oils, it is the most favorable raw material for bio-based diesel in numerous Europe countries (80 percent). The Jatropha Curcas plant yields jatropha oil. Because of its high ratio of seed fabrication and ability to grow in almost any terrain, it has become the most popular plant for bio-based diesel generation in recent years. Because of its high fatty acid content, it's also utilized to make lubricants [54, 55]. Coconut oil contains a lot of saturated fats, so it takes a long time to oxidize. Owing to its derivatives such as fatty acid of coconut, it can be used as a transformer oil and lubricant. It can also be used as a bio-based diesel raw material because of its high viscosity. Rice bran oil is made from rice husk and has a high smoke point and a high percentage of oleic acid (38.4%) in its fatty acid formation, making it ideal for lubricant use. Palm oil has a high concentration of palmitic acid (saturated fat), as well as oleic acid (monounsaturated) as a main factor, making it perfect for lubricant treating. It also has a strong load carrying capability [56]. Aside from that, it has specific drawbacks, such as oxidative and thermal stability.

Plant oil-sourced lubricants shown excellent parameters about friction and wear resistance than mineral-sourced oil specially on limited lubrication regimen. This is because of metallic soap sheet's structure from the fatty acid molecules' reaction with metal superficies in the course of process. Such reaction concluded in less friction coefficient, but much more in all friction and wear volume. Much more wear and friction volume can be associated with the superficies materials being loss because of metallic soap sheets structure repeated and the peroxides' corrosive effect and free fatty acids as oxidation's products. With suitable formularization with complements such as antioxidants and so on, bio-sourced lubricants can conduct much better than traditional lubricant for diverse implementations. This can be certified to their better lubricity and higher flash point crosschecked to mineral-sourced oils. Decreased friction losses in machineries and engines can conclude in lesser fuel or energy usage, which in turns concluded in lesser operating expense and less detrimental gases emissions to the ecology. Bio-sourced lubricants were obtained to show a few important features which do them excellent to mineral-sourced oils for several implementations. This contains less evaporating structural combination emission for engine oil implementation, satisfying emulsifiability for metalworking fluids implementation, quick air release ratio and low compressibility for hydraulic implementation, favorable dielectric resistance for converter implementation and so on.

In the future, it is suggested that researches should concentrate on the continual development of manufacturing effectiveness, especially for big scale aims. By genetic engineering, this contains the improvement of effective catalyst and discovery of reliable and cheaper raw materials. Though numerous researches concerning bio-sourced lubricants have been reported with several final materials are present as commercial, there is the require for more systematical studies that verifies the friction and wear case of diverse bio-sourced lubricant obtained from diverse raw materials, manufacturing blends and methodologies. In the event of existing lubricants prepared for a particular kind of implementation, it is suggested to conduct a sequence of complete analysis that contains the lubricant integration within the real scheme. This is actually a field worth of research, and the outcomes will be beneficial to improve novel lubricants with excellent features. The structure of saturated fatty acid and unsaturated fatty acid of vegetable oils analyzed are given in Table 1 and Table 2, respectively [57]. The unsaturation's degree and the fatty acid's structural contents of plant oils analyzed are given in Table 3 and Table 4, respectively [57]. The cost of vegetable oils used at bio-lubricant manufacturing is displayed in Table 5.

Table 1. The structure of saturated fatty acid of vegetable oils analyzed.

Vegetable Oil	**Saturated fatty acids (%)**								
	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C20:0	C22:0	C24:0
Castor	–	–	–	–	1.30	1.20	–	–	–
Soybean	–	–	–	0.06	9.90	3.94	0.41	0.48	0.21
Olive	–	–	–	–	16.50	2.30	0.43	0.15	0.06
Sunflower	–	–	0.02	0.09	6.20	2.80	0.21	–	0.31
Rapeseed	–	0.01	–	–	4.60	1.70	–	–	–
Jatropha	-	-	-	-	6	-	-	-	-
Coconut	7.60	5.50	47.70	19.90	–	2.70	–	–	–
Rice bran	–	–	–	0.39	20.0	2.10	–	–	–
Palm	–	–	–	1.12	42.70	4.55	0.39	0.58	0.06
Cottonseed	–	–	–	0.77	21.87	2.27	0.26	0.36	0.12
Sesame	–	–	–	–	9.70	6.50	0.63	0.14	–
Moringa	-	-	-	-	6.5	72.2	2	-	-
Corn	–	–	–	–	10.34	2.04	0.44	0.31	0.26

Table 2. The structure of unsaturated fatty acid of vegetable oils analyzed.

Vegetable Oil	**Unsaturated fatty acids (%)**									
	C16:1	C17:1	C18:1	C18:2	C18:3	C20:1	C20:2	C22:1	C22:2	C24:1
Castor	–	–	89.70	7.30	0.50	–	–	–	–	–
Soybean	0.08	0.08	21.35	56.02	7.15	0.22	–	–	–	–
Olive	1.80	–	66.4	16.40	1.60	0.30	–	–	0.05	–
Sunflower	0.12	–	28.0	62.2	0.16	0.18	0.09	–	–	0.39
Rapeseed	0.21	–	64.7	19.60	1.20	9.10	–	–	–	–
Jatropha	-	-	50	30.2	-	-	-	-	-	-
Coconut	–	–	6.20	1.60	–	–	–	–	–	–
Rice bran	0.19	–	42.70	33.1	0.45	1.11	0.11	–	–	0.38
Palm	–	0.06	39.37	10.62	0.21	0.17	–	–	–	0.06
Cottonseed	0.47	0.11	16.61	56.35	0.33	0.14	0.10	–	–	0.16
Sesame	0.11	–	41.5	40.9	0.21	0.32	–	–	–	–
Moringa	2	1	-	-	4	-	-	-	-	-
Corn	–	0.05	24.23	60.38	0.99	0.28	–	–	–	0.20

Table 3. The unsaturation's degree of analyzed vegetable oils.

Vegetable oil	Unsaturation's 'unweighted' degree	Unsaturation's 'Partially weighted' degree	Unsaturation's 'Fully weighted' degree (double bonds' mean number)
	(%)	b	c
Castor	0.90	1.01	1.01
Soybean	0.84	1.44	1.51
Olive	0.85	0.96	0.97
Sunflower	0.89	1.57	1.57
Rapeseed	0.93	1.24	1.32
Jatropha	0.78	1.15	1.15
Coconut	0.09	0.12	0.12
Rice bran	0.78	1.14	1.15
Palm	0.51	0.62	0.62
Cottonseed	0.71	1.27	1.27
Sesame	0. 79	1.37	1.59
Moringa	0.92	1.12	1.11
Corn	0.86	1.45	1.45

[a] Overall unsaturated fatty acids supposed to have the identify weight percent.
[b] Overall unsaturated XX: y (y-2) fatty acids have a weight percent of two.
[c] XX: three fatty acids a weight percent of 3, XX: 2 fatty acids have a weight percent of two and so on.

Table 4. The fatty acid's structural contents of plant oils analyzed.

Vegetable Oil	C	H	O
	(% w/w)	(% w/w)	(% w/w)
Castor	76.57	11.94	11.42
Soybean	77.03	11.90	10.95
Olive	76.91	11.66	10.95
Sunflower	76.90	11.84	10.98
Rapeseed	77.07	11.84	10.93
Jatropha	76.57	12.21	11.32
Coconut	72.75	11.65	11.01
Rice bran	76.22	12.38	11.26
Palm	76.09	12.44	11.27
Cottonseed	76.86	11.89	11.21
Sesame	77.02	11.98	10.87
Moringa	76.16	11.73	11.83
Corn	76.71	11.52	10.98

Table 5. The cost of vegetable oils used at bio-based lubricant manufacturing

vegetable oil	Castor	Soybean	Olive	Sunflower	Rapeseed	Jatropha	Coconut	Rice bran	Palm	Cottonseed	Sesame	Moringa	Corn	ISO VG46
Cost (Per Liter)	12,15	3.99	20.00	3.35	4.62	197.00	19.21	195.00	1.22	2.65	74.64	209.00	12.00	2.00

2.1 Limitations and advantages of vegetable-sourced lubricants used in automotive industry

It is clear that the lubricants are plant oils in their natural state. Plant oil as a bio-lubricant has specific benefits or drawbacks relying on the raw material utilized to manufacture lubricants in different technological and other lubrication operations. The advantage of utilizing plant oil is that it has high class lubricity to mineral-based oil. In reality, these plant oils' lubricity is so high that friction materials must be applied to certain applications, like tractor transmissions, to prevent clutch slip. The viscosity index, which calculates the fluid's viscosity change as a function of temperature, is another factor to consider. To put it another way, oil with a high index of viscosity reacts to temperature less than oil with a low index of viscosity. Plant oils have a high viscosity index as well [58]. Plant oils have a high flash point as opposed to mineral oils, which is considered an essential feature. Most notably, plant oils are less harmful, biodegradable in nature, and a renewable resource that reduces reliance on petroleum oil imports [59].

Together with their benefits, plant oils have some drawbacks, like less oxidative stability; numerous plant oils may not have enough stability of oxidative in their natural state to be used as lubricants. Antioxidants can be utilized to address this restriction, but this chemical change will conclude in fatty acid shifting because of the superficial hydrogenation operation, as well as a raise in the final product's cost. With latest advancements in biotechnology, the genetically developed oil seeds' production do not need chemical alteration and are naturally stable or the use of antioxidants has accelerated. The amount of carbon dioxide produced or the amount of oxygen consumed is measured to determine the biodegradability degree. When compared to petroleum-based oils, which biodegrade at about 15 to 35 %, most plant oils tend to biodegrade in surplus of 70 percent within that time frame. In order for a test to be deemed easily biodegradable, it must degrade by more than 60% in less than 28 days. Likewise, the toxicity of plant oils can be predicted using a variety of analysis including daphnia, fish, and other species. In this scenario, both vegetable oil and mineral oil have low toxicity in their natural state, but when supplements are added, the toxicity level increases. The other thing to think about is high of their pour point. Chemical additives may be used to solve the trouble and lesser the pour point using the winterization process. For this aim, diverse artificial oils can be used.

3. Criterion Weighting Method

Multi-criteria decision making is a sub-discipline of operations research that examines several competing criteria in decision making (both in daily life like and in engineering and business settings). When assessing alternatives, it is common to have conflicting criteria: one of the key criteria is generally efficiency or cost, and another criterion is usually several calculations of attributes, which is often in disagreement with the cost. If the risk is big, it is critical to use an appropriate hierarchy of the problem [60]. When complex problems are well-structured and various parameters are explicitly considered, more educated and better decisions are made. Due to the progress in contemporary multi-criteria decision-making discipline, significant progress has been made in this area. A range of techniques and strategies have been created for use in a variety of fields, ranging from industry and politics to the energy and environment [61], many of which are applied through advanced decision-making simulations [62, 63]. In brief, multi-criteria decision-making denotes the operation of evaluating the best convenient resolution with respect to problems and established criteria that are widespread formations in daily life [64].

The criterion weighting methodology is one of the methodologies defined for multi-criteria decision making. The criterion weighting methodology [60] is a constructed method which was initially developed by Saaty [65] for analyzing and organizing complicated decisions. The criterion weighting methodology indicates an exact strategy to quantification of the decision-criteria. The criterion weighting methodology starts by breaking down the decision issue into a series of sub-problems. Later the decision maker uses pairwise comparisons to assess the relative value of its different components. Professionals' individual experimentations are used to predict the factors' relative magnitudes by pairwise comparisions. Each interlocutor crosschecks the relative significance each double of items utilizing an especially planned survey. The criterion weighting methodology transforms these ratings into digital valuations (priorities or weights), which are used to assign one score to each option [65]. The degree to which the decision maker has been coherent in his replies is gauged by the consistency index.

This study involves physical and chemical features of the selected plant oil-sourced lubricants. The vegetable oil-based lubricants' properties are kinematic viscosity (40^0C), density (15^0C), kinematic viscosity (100^0C), flash point, viscosity, acid value, and pour point. The 13 various options are defined for the aim of this research. These alternative lubricants are compared using the criterion weighting methodology. The selected alternatives' physicochemical properties are presented in Table 6 [57].

Table 6. Physicochemical features of analyzed vegetable oil-derived lubricants

	Kinematic Viscosity	[a]Density @ 15 °C	Viscosity	Kinematic Viscosity	[b]Acid value	Pour point	Flash point	Reference
	@ 40 °C mm^2/s	kg/m^3	index	@ 100 °C mm^2/s	mg KOH/g	K	K	
Jatropha	40.0	0.917	170	5.50	4.65	270	546	[66]
Castor	220.6	0.950-0.970	220	19.72	1.40	246	523	[67]
Olive	39.62	0.914-0.925	190	8.24	1.10	270[b]	591[b]	[68]
Rapeseed	45.60	0.910-0.917	180	10.07	1.50	261	513	[67]
Sunflower	40.05	0.920-0.927	203	8.65	0.30	261	525	[67]
Soybean	28.86	0.922-0.934	246	7.55	0.30	264	598	[69]
Cottonseed	33.86	0.917-0.931	211	7.75	-		525	[70]
Sesame	27.33	-	193	6.3	2.00	268[b]	589[b]	[71]
Rice bran	40.6	-	201	8.7	-	260	591	[72]
Coconut	24.8	0.919-0.937	169	5.5	-	294	598	[72]
Moringa	44.88	-	-	-	-		477	[73]
Palm	39.4	-	-	-	0.50	297	525	[74]
Corn	32.41	0.916	238	8.06	0.30	259[b]	597[b]	[75]
ISO VG46	>41.4	-	>90	>4.1		267	493	[76]

[a] [77] [b] [78]

Based on the pair-wise comparison, the decision matrix presented in Table 7 is constructed. The table indicates the relative priorities of the fuel characteristics used.

Table 7. Decision Matrix

Matrix	Kin. Viscosity (40°C)	Density	Viscosity	Kinematic Viscosity	[b]Acid value	Pour point	Flash point	Cost	**Normalized Principal Eigenvector**
Kin. Viscosity (40°C)	1	5	4	2	6	7	3		33,60%
Density	1/5	1	1/3	1/5	1/2	1/2	1/3		3,89%
Viscosity	1/4	3	1	1/5	2	3	1/5		7,88%
Kin. Viscosity (40°C)	1/2	5	5	1	3	4	2		22,90%
Acid Value	1/6	2	1/2	1/3	1	1/2	1/7		4,56%
Pour Point	1/7	2	1/3	1/4	2	1	1/9		4,86%
Flash Point	1/3	3	5	1/2	7	9	1		22,30%
Cost									33,60%

According to the resulting relative priorities presented in Figure 1; kinematic viscosity at 40°C, viscosity, and kinematic viscosity at 100°C are determined to be the criteria with the highest impact on the alternatives lubricants.

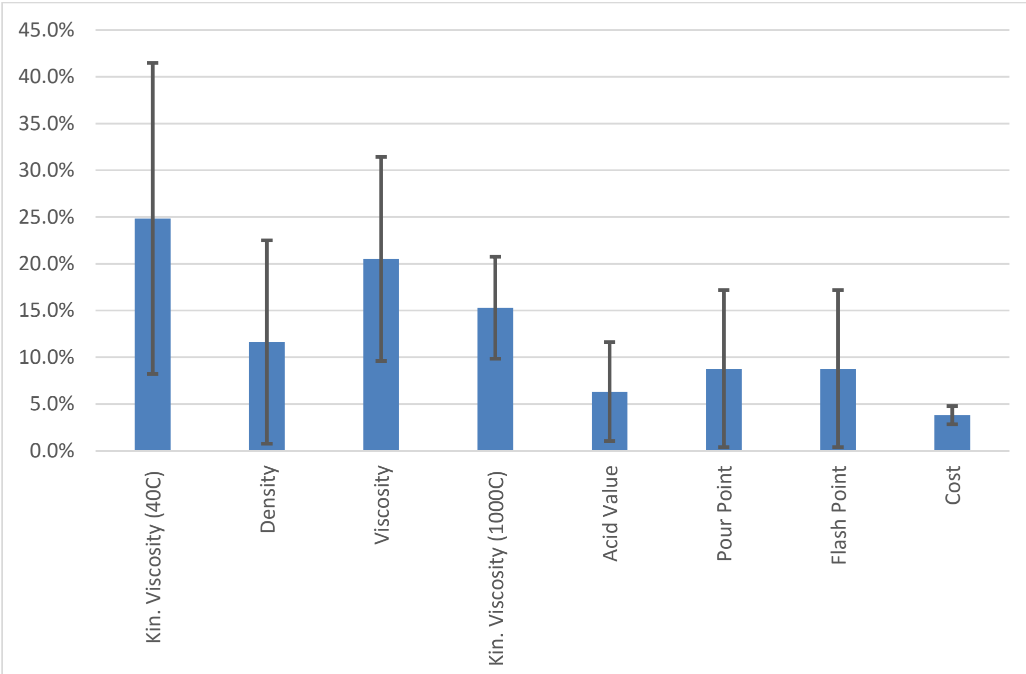

Figure 1. Relative priorities of the criteria

For the purpose of this study, 13 vegetable oil alternatives are determined. The list of these alternatives along with their characteristics was provided in Table 8.

Table 8. Resulting Scores of Vegetable Oil Lubricants

	Jatropha	Castor	Olive	Rapeseed	Sunflower	Soybean	Cotton-seed	Sesame	Rice bran	Coconut	Palm	Corn	ISO VG46
Kin. Viscosity (40°C)	40	220.6	39.62	45.6	40.05	28.86	33.86	27.33	40.6	24.8	39.4	32.41	41.4
Density	0.917	0.96	0.92	0.914	0.924	0.928	0.924	0.9247	0.9247	0.928	0.924	0.916	0.916
Viscosity	170	220	190	180	203	246	211	193	201	169	192.5	238	90
Kin. Viscosity (100°C)	5.5	19.72	8.24	10.07	8.65	7.55	7.75	6.3	8.7	5.5	8.345	8.06	4.1
Acid Value	4.65	1.4	1.1	1.5	0.3	0.3	1.33	2	1.33	1.33	0.5	0.3	1.33
Pour Point	270	246	270	261	261	264	268	268	260	294	297	259	267
Flash Point	546	523	591	513	525	598	525	589	591	598	525	597	493
Cost	197.00	12.15	20.00	4.62	3.35	3.99	2.65	74.64	195.00	19.21	1.22	12.00	2.00

Table 9 further presents the normalized values of the alternatives, their priority values for each fuel characteristic, and the overall scores as indicated in the last row of the table. The values in the Table 9 are divided by the sum of each row to find the normalized values. Table 9 provides these normalized values.

Table 9. Normalized Priorities

	Jatropha	Castor	Olive	Rapeseed	Sunflower	Soybean	Cotton-seed	Sesame	Rice bran	Coconut	Palm	Corn	ISO VG46
Kin. Viscosity (40°C)	0.0611	0.3370	0.060	0.0697	0.0612	0.0441	0.0517	0.0418	0.0620	0.0379	0.060	0.049	0.063
Density	0.0763	0.0799	0.076	0.0760	0.0769	0.0772	0.0769	0.0769	0.0769	0.0772	0.077	0.076	0.076
Viscosity	0.0679	0.0879	0.075	0.0719	0.0811	0.0983	0.0843	0.0771	0.0803	0.0675	0.077	0.095	0.035
Kin. Viscosity (100°C)	0.0507	0.1818	0.076	0.0928	0.0797	0.0696	0.0714	0.0581	0.0802	0.0507	0.077	0.074	0.037
Acid Value	0.2677	0.0806	0.063	0.0864	0.0173	0.0173	0.0766	0.1151	0.0766	0.0766	0.029	0.017	0.076
Pour Point	0.0775	0.0706	0.077	0.0749	0.0749	0.0758	0.0769	0.0769	0.0746	0.0844	0.085	0.074	0.076
Flash Point	0.0757	0.0725	0.081	0.0711	0.0728	0.0829	0.0728	0.0816	0.0819	0.0829	0.072	0.082	0.068
Cost	0.3596	0.0222	0.036	0.0084	0.0061	0.0073	0.0048	0.1362	0.3559	0.0351	0.002	0.021	0.003

These normalized values are then multiplied with the relative weights of each factor to obtain the weighted-priorities of the alternatives which constitutes Table 10.

Table 10. Resulting Scores of Vegetable Oil Lubricants

	Jatropha	Castor	Olive	Rapeseed	Sunflower	Soybean	Cotton-seed	Sesame	Rice bran	Coconut	Palm	Corn	ISO VG46
Kin. Viscosity (40°C)	0.0205	0.1132	0.020	0.0234	0.0206	0.0148	0.0174	0.0140	0.0208	0.0127	0.020	0.016	0.021
Density	-0.0030	-0.0031	-0.003	-0.0030	-0.0030	-0.0030	-0.0030	-0.0030	-0.0030	-0.0030	-0.003	-0.003	-0.003
Viscosity	0.0054	0.0069	0.006	0.0057	0.0064	0.0077	0.0066	0.0061	0.0063	0.0053	0.006	0.007	0.002
Kin. Viscosity (100°C)	-0.0054	-0.0193	-0.008	-0.0098	-0.0084	-0.0074	-0.0076	-0.0062	-0.0085	-0.0054	-0.008	-0.007	-0.004
Acid Value	-0.0628	-0.0189	-0.014	-0.0202	-0.0040	-0.0040	-0.0180	-0.0270	-0.0180	-0.0180	-0.006	-0.004	-0.018
Pour Point	0.0281	0.0256	0.028	0.0272	0.0272	0.0275	0.0279	0.0279	0.0271	0.0306	0.030	0.027	0.027
Flash Point	0.0372	0.0356	0.040	0.0350	0.0358	0.0408	0.0358	0.0401	0.0403	0.0408	0.035	0.040	0.033
Cost	0.2230	0.0138	0.022	0.0052	0.0038	0.0045	0.0030	0.0845	0.2208	0.0217	0.001	0.013	0.002
Total Scores	**0.2431**	**0.1539**	**0.091**	**0.0634**	**0.0782**	**0.0809**	**0.0622**	**0.1365**	**0.2859**	**0.0849**	**0.076**	**0.090**	**0.062**

The results in Table 10 indicate that Rice bran has the highest score (0.2859) among all other alternatives.

4. Results and Discussion

To meet the supply and demand of natural gas and oil in the next will be too difficult and happen a primary apprehension all around the world. Expenditure of petroleum-based energy resources together with critical environmentally damage are recently the troubles under discussion. The petroleum-based and synthetically lubricants are greatly utilized in the market, because of the mineral-based sources' continuous manufacturing they occur limited and they also affect the ecological circumstances which could increase the greenhouse gas emissions. The plausible resolution is renewable energy sources or alternative products which either in the bio-lubricants or biodiesel forms. This would be the evident solution to move beyond the traditional energy sources. The bio-degradability ratio of modified lubricants is great in addition to their superiority in toxicity and cost [79].The bio-sourced lubricants currently getting significance as an alternative product in numerous diverse implementations [80].

The purpose of this study is to choose the most feasible vegetable oil-sourced lubricant for automotive implementations depending on the investigations in recent years. For this purpose, a list of characteristics is evaluated. Finally, the criterion weighting methodology is implemented to the emerging scheme. The implementation of the results from this study provides an opinion of how the criterion weighting modeling can be applied to the evaluation of vegetable oil-sourced lubricants. The obtained results as shown in Table 10 indicate that the Rice bran-based lubricant is the alternative that helps the most to the objective of choice the most efficiency vegetable oil that accomplishes overall the criterions chosen.

The conclusions of this study aids investigators working on a wide range of areas regarding lubricants compare relative effects of the fields in which they can potentially contribute. In a worldwide framework, playmakers can also benefit from this analysis's results through evaluation of the multidirectional efficiency of their research and development investing on lubricants. The provided data in this paper can be of help for the experts, policy-makers and researchers involved in the lubricant sector take an efficient stage to address the difficulties in front of the purifier lubricants generation through trusting on maintainable oil-bearing sources. Introduction of further variables under various categories are considered for further research on this end. Increasing the number of experts in the phase of evaluating the increased number of variables is another potential for further research.

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