Characterization and Evaluation of Fuel Properties of Pupae Biodiesel-Diesel Blends

Pradeep N R[1], S Kumarappa[2], B M Kulkarni[3]

[1]*Department of Mechanical Engineering, Bapuji Institute of Engineering and Technology, Davangere, Karnataka, India*
[2]*Department of Mechanical Engineering, Bapuji Institute of Engineering and Technology, Davangere, Karnataka, India*
[3]*Department of Chemical Engineering, Bapuji Institute of Engineering and Technology, Davangere, Karnataka, India*

***Abstract*-Biodiesel, an alternative diesel fuel derived from vegetable oil, animal fat, or waste vegetable oil (WVO). In this studies animal fat (dead pupae) can be used an alternative fuels for CI engines. The present study was therefore designed to convert the oil in the waste pupae to methyl ester and to evaluate its potential as biodiesel. In this view the properties measurement of biofuels and its blends with diesel were carried.**

Biofuel selected for the properties measurement is pupae oil. It is added in proportions with pure diesel so as to biodiesel form. The blends of the biodiesel are formed in volume proportions of 10, 15, 17, 20, 23, 25, 30, 40, 50, 60, 70, 80, 90 and 100 % with commercial diesel. The various physical and the chemical properties of these biodiesel and its blends with diesel were measured. From the measured properties of biodiesel were plotted on volume ratio. Also comparative studies of these properties of the blends are discussed in terms of its suitability as fuel in the CI engine. The main objective of this study is to find the suitability of these biodiesel and its blends as alternative fuel for CI Engine.

***Keywords*-silkworm pupae, pupae oil, transesterification, pupae biodiesel**

I. INTRODUCTION

Biodiesel through alternative is not viable because of its high cost. High price of biodiesel mainly due to extensive use of high valued refined vegetable oils for biodiesel manufacturing. To reduce its cost, a wide variety of vegetable oils which are available large excess have been reported. This has resulted in the wide variation in fuel properties of biodiesels produced. As a result each country has specified their own norms for biodiesel trading so as to suit and protect interests of local crops of those regions. Vegetable oil is good source for the production of biodiesel but with the limitation of food resource. It is necessary to look for the other sources such as animal fats. This is majorly found in butcher shops as waste. One of major source is found in silk reeling industry such as waste pupae. It is goof source of fats and lipids .In India, about 1800MT of Pupae is produce from that it can produced 200MT of Pupae oil and about 150MT of Biodiesel per annum it can fill full the requirement of fossil fuel.

Silk is known all over the world for its unique golden colour, durability and texture. Silk [1, 2] occupies a prominent position in the cultural heritage of the Indian people. Silkworm rearing, reeling and weaving of silk not only represent the tradition of India. Pupa, which constitutes the major portion of the cocoon weight, is an inevitable byproduct generated in large quantity (75-85%) during the cocoon production. After the reeling is over, the inner pupae are thrown as waste, which putrefy and cause environmental pollution. It has been reported by many workers that these waste pupae have tremendous potential for use as poultry feed. The same study [3] also revealed that the dry waste pupae contain considerable amount of lipid (20 25%).

In India especially southern states of India, Karnataka and Andra Pradesh in particular, are known for the sericulture activities. Production of silk is a common practice among quite a large section of population in this region. The host trees for sericulture grow abundantly in Karnataka and Southern states of India as the climate here is suitable for those plants. The sericulture activities generate huge quantities of the waste silkworm pupae after production of the silk from cocoons. Previous has shown that the waste pupae contain 35-40% oil along with many other essential nutrients. Most of the waste pupae is used as fertilizer and a small amount is used as poultry feed. The major difficulty in storing the waste pupae is its bad smell and poor shelf life. The dumping of the huge waste of the silk industries poses a threat to the environment. In a recent study the authors reported conversion of the lipid fraction of waste pupae into biodiesel [4], Biodiesel is a non-toxic renewable energy source. It consists of monoalkyl esters of long chain fatty acids. It is derived from vegetable oils and animal fats via transesterification reaction. The animal or vegetable oils are converted into biodiesel when one mole of triglyceride reacts with three moles of alcohol (such as methanol or ethanol) to produce a mole of glycerol and three moles of monoalkyl esters (biodiesel) [5, 9]. Methanol is the most commonly used alcohol in the commercial production of biodiesel because of its low price [6]. The reaction requires a catalyst, usually a strong acid or base such as sulphuric acid sodium or potassium hydroxide, and produces new chemical compounds called methyl esters. These esters that have come to be known as biodiesel. Biodiesel is usually blended with petroleum based diesel though it also can be used in pure form with some modifications of engines [7, 11]. Blends are indicated by the abbreviation BXX, where XX is the percentage of biodiesel in the mixture.

II. PRESENT WORK

The silkworm is the larva or caterpillar of the domesticated silk moth, Bombyxmori. It is an important economic insect since it is the producer of silk. Sericulture has been practiced for at least 5,000 years in India. The silkworm larvae themselves in a cocoon of raw silk produced in the salivary glands that provide protection during the vulnerable, almost pupal state. The cocoon is made of thread of raw silk from 300 to 900meters long. If the animal is allowed to survive after spinning its cocoon, it releases proteolytic enzymes to make a hole in the cocoon so that it can emerge as a moth. This would cut short the threads and ruin the silk. In order to prevent this, silkworm cocoons are boiled. The heat kills the silkworm and the water makes the cocoon easier to unravel. After this process the silkworm pupa will be discarded as a waste material from the silk industries which is rich in proteins, fats and carbohydrate. This pupae waste has got potential applications as a food for poultry and pedigree and is also used in pharmaceutical industry. However the concern about production of Biodiesel from silkworm pupae waste can save a new way to meet the demand of fuel consumption as well as utilize the pupae waste efficiently. Silkworm pupa is found rich in carbohydrates (40-45% dry weight) and fats (30% dry weight) which can be extracted easily.

Silkworm pupae oil is too thick and viscous to get through the fuel pump and injectors. Instead silkworm pupae oil can be mixed with diesel in different percentage with volume ratio. Silkworm pupae oil-diesel blends or convert it to biodiesel thus can be used in a diesel engine without any major engine modification.

III. LITERATURE SURVEY

Biofuels History

The concept of using alternative fuels is not contemporary in its nature; it has existed for many years. Alternative diesel engine fuels that have been researched over the years range from coal to peanut oil [9]. During the 1900 Paris World Fair, the Rudolf Diesel ran the Diesel Engine on peanut oil. A Belgian patent granted in 1937 to G. Chavannes displays the early existence of the use of ethyl esters extracted from palm oil.

However, inexpensive petroleum-based fuels prevented biodiesel fuels from receiving much consideration, resulting in adoption of a diesel engine to specifically burn petroleum diesel. Interruption of cheap oil supplies resulting from the 1973 oil embargo as well as the 1990 Gulf War sparked a renewed interest and research in using domestically grown and renewable sources for fuel production. Although the use of biodiesel did not receive much attention in the United States until the late 1990s [9], it has been used extensively in Europe for nearly a quarter of a century. It is important to understand how a diesel engine functions in order to understand the necessary characteristics of biodiesel and why biodiesel is a suitable alternative fuel for petro-diesel.

F. Halek et al., [1] Biodiesel derived from vegetable oil or animal fats is recommended for use as a substitute for petroleum-based diesel mainly because biodiesel is a renewable, domestic resource with an environmentally friendly emission profile and is readily biodegradable. The use of biodiesel has grown dramatically during the last few years. Feedstock costs account for a large percent of the direct biodiesel production costs, including capital cost and return Vegetable oil. The cost of biodiesel is lower than diesel fuel. Biodiesel has some benefits such as Cheaper fuel for consumers, More energy security & diversified sources, Higher farm incomes & rural employment, Significant carbon emission reduction, Lower Imports & energy prices.

M. Sharma1 et al., [2] Eri silk is a fine quality silk obtained from the silkworms reared on castor leaves. It comprises of about 8% of the total silk produced in India. It is produced as almost a household activity in certain parts of North-eastern India. The sericulture activities generate huge quantities of the waste silkworm pupae after production of the silk from cocoons. The dumping of this huge waste poses a threat to the environment of the locality. Recent studies have shown that these waste pupae contain 30% or more lipid. The lipid part of the waste eri silkworm pupae can be transesterified with methanol to produce methyl esters of fatty acids. The present study reports a quick and efficient transesterification method to convert the lipid to fatty acid methyl ester. The physicochemical properties of the methyl ester are reported. The parameters fulfill the international requirement for biodiesel. Thus the present work shows that this bio-waste can be converted to good quality fuels which may be used as biodiesel additives.

M. Sharma et.al., [4] States the waste silkworm pupae contain high percentage of oil 30-40%, which can be converting into Biodiesel. On the basis of FFAs and water content in the oil, the trans-etherification can be carried out using methanol to oil. The ester formation takes place of 65Oºc taking 3.94% NaOH at temperature at 600ºC for 2 h reaction time. All of the parameters determined for the methyl ester of the oil comply with the ASTM Standard.

Angelo C et al.,[5] the transesterification process in an industrial unit can be summarized as following; the oil, after acid correction is transferred to the principal reactor. In a second reactor, the catalyst (KOH or NaOH) and the alcohol (NaOH or KOH) are organized and transferred to the principal reactor. The reaction is completed in 50 min, at temperature between 50 to 60ºC. The biodiesel (upper layer) is then separated from the raw glycerin (lower layer) by decantation (on batch process) or by centrifugation (on continuous process). The lower layer, besides raw glycerin, contains part of the alcohol that could be recovered and reused in the process.

SupanidaWinitchai et al.,[8] The silkworm pupae oil, it is an interesting sub product obtained after the extraction procedure of silk threads already. Remainder when bring separate the Soxhlet extraction by Hexane the percentage of oil were in the ranging 35%-40 %. The study of oil properties that the effective extraction show that, silkworm oils is very high food value and human, when consider from the components of the fatty acids, such as α-linolenic acid were in the rang 32-47 %.which, the essential fatty acid wants the body wants but could not establish get in the body must received from the nutrient ion. The analyzed quality of oils it was found that quality value be in line for the standard of oil and the fat for consuming. The possibility in selecting the suitable varieties of silk as source of protein and fat which could be develops for food and cosmetic products.

Shashi Kumar Jain et al., [9] Stated that major economic factor to consider for input costs of biodiesel production is the feedstock, which is about 80% of the total operating cost. Other important costs are labor, methanol and catalyst, which must be added to the feedstock.

Jon Van Gerpen [11]. Biodiesel production from different oil is high content of FFA has been investigated. In alkali base catalyzed trans-esterification process, the presence of high concentration of FFA reduced the yield of methyl esters of fatty acids significantly. A two stage trans-esterification process was selected to improve the methyl ester yield. The first stage was acid pretreatment process, which could reduce the FFA levels less than 1%. The second stage, alkali base catalyzed trans-esterification process gave 90% methyl ester yield.

In order to provide a wide and complete evaluation of the potentialities of biodiesel as alternative fuel, further investigations have to be performed at larger scale. A higher temperature can be used in combination with higher pressure, but this is expensive. Methanol and oil do not mix; hence the reaction mixture contains two liquid phases. Other alcohols can be used, but methanol is the least expensive. To prevent yield loss due to Saponification reactions (i.e. soap formation), the oil and alcohol must be dry and the oil should have a minimum of free fatty acid.

A. Silkworm Pupae

Pupae used for present investigations were obtained from sericulture department. Tolhunase. About 10 kg's of pupae wastes was collected for each trial run. Pupae as received and properties determined and reported in Fig.1 & Table 1.Pupae oil used for characterization was produced from extraction of dried pupae by solvent extraction operation and oil was produced. Sample of oil is stored in an air tight container. Physical and chemical properties were determined as per ASTM methods.

Fig.1. Dead Pupae

Table 1. Properties of Dead Pupae

Appearance	Oval shape, non-sticky
Colour	Dark brown
Smell	Unpleasant,
Weight	0.6-1.2 gms
Diameter	6-8 mm
Length	12-20 mm
Bulk Density	850 -860 kg/m^3
Bed Porosity	0.6-0.66
Pupae Density	1200-1200 kg/m^3
Moisture content	130-150 %

B. Pupae Oil

Pupae oil used for characterization was produced from extraction of dried pupae by solvent extraction operation. Sample of oil is stored in an air tight container.

C. Pupae-Biodiesel Production

Biodiesel from pupae oil was produced from conventional alkali (KOH) catalyzedtransesterification process as shown in figure 2. Excess methanol used was recovered first by batch distillation and allowed to settle. Glycerin settled at the bottom was taken out, top layer was repeatedly washed with water to remove alkali and again allowed to settle. Top oily layer was batch distilled to drive out any moisture present (120ºC). Residual product was collected. Properties of biodiesel tested for its fuel properties were as per ASTM.

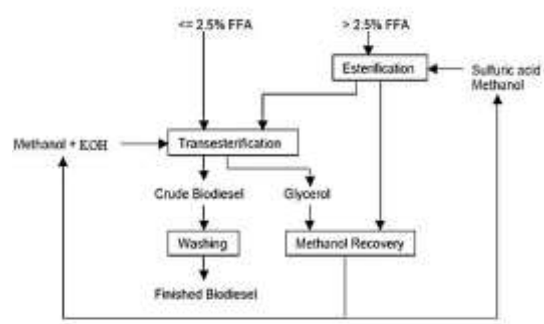

Fig.2. Process flow for Biodiesel Production

IV. RESULTS AND DISCUSSION

A. *Fuel Properties*

The physicochemical properties of the oil extracted from waste pupae are listed in Table 2.The percentage of oil in the silkworm pupae sample was found to be 35%.

Table 2. Properties of Pupae oil and Pupae Biodiesel

SI.No	Properties	Pupae oil	Pupae Biodiesel (B100)	ASTM D6751
1	Flash Point(ºC)	180	93	130 to 170
2	Fire Point (ºC)	215	102	-
3	Cloud Point (ºC)	13	12	3 to 12
4	Pour Point (ºC)	9	6	-15 to 10
5	Kinematic Viscosity(40˚C) (cSt)	34.4	3.1	1.9 - 6.0
6	Saponification Value	220	191.48	-
7	Calorific Value (MJ/Kg)	37.2	32.73	-
8	Cetane number	-	50.05	-
9	Density(Kg/m^3)	940	870	-
10	Iodine number	131	-	-
11	Free fatty acids	0.32	0.30	-

B. *IR Spectra Studies of pupae oil and pupae biodiesel*

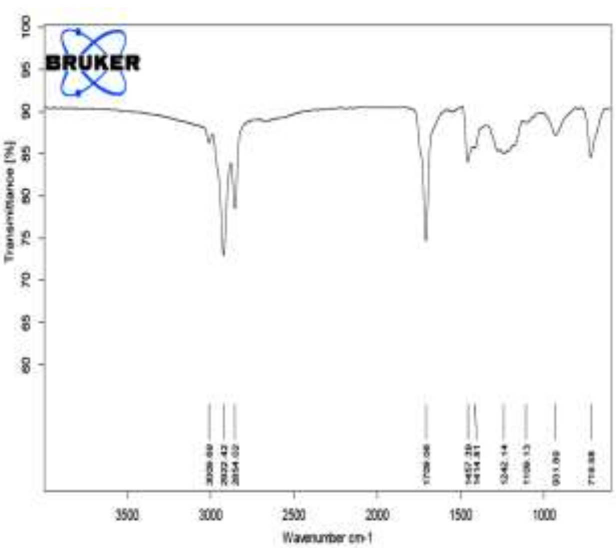

Fig. 3. IR Spectra of pupae oil

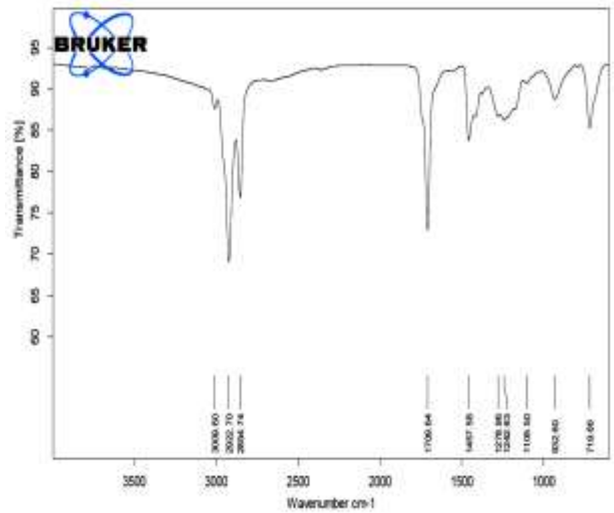

Fig.4. IR Spectra of pupae biodiesel

The FTIR spectra of biodiesel prepared from pupae oil showed the presence of pronounced functional groups, which indicates the presence of alkanes and the absence of phosphorus and sulfur. A typical FTIR spectrum of transesterified pupae oil showed that it contained significant amount of esters. The comparative frequency ranges of the spectra, and their corresponding functional groups and indicated compounds are presented in Figure 3 and figure 4. Different bonds were present in biodiesel (C-C, C C, C-O, C = O etc.) and they have different vibrational frequencies. The presence of these bonds in biodiesel could be detected by identifying characteristic frequencies as transmittance bands in the infrared spectrum. From the spectrum, it observed that the peak of C=O vibration band at 1709.6 of methoxy carbonyl group had a transit to 1709.0 cm−1 in oil to 1709.6 cm−1 in biodiesel. Biodiesel could be elucidated from the transmittance peak at 1709.6 cm−1 corresponding to C=O stretching and hence the resultant product was confirmed as methyl ester. In addition to this, the peak at 3006 cm−1 was attributed to –HC = CH– stretching of methyl ester. The vibrational peak that appeared at 2922.4 cm−1 of biodiesel was corresponded to asymmetric CH3 stretching of weaker band. The asymmetric and symmetric CH3 deformations were observed near 1457.3 cm−1 and 1414.8 cm−1 respectively. The vibrational peak at 931.8 cm−1 was assigned to C-O-C stretching. Actually, esters were characterized by the strong absorption due to C=O stretching frequency near 1709.6 cm−1 and by the strong absorption involving the stretching of C-O near 1242.1 cm−1. From this spectrum, the compound produced was confirmed as methyl ester (biodiesel).

C. *Fuel Properties of Pupae Bio-diesel and its blends*

1) *Density of pupae biodiesel-diesel blends:*

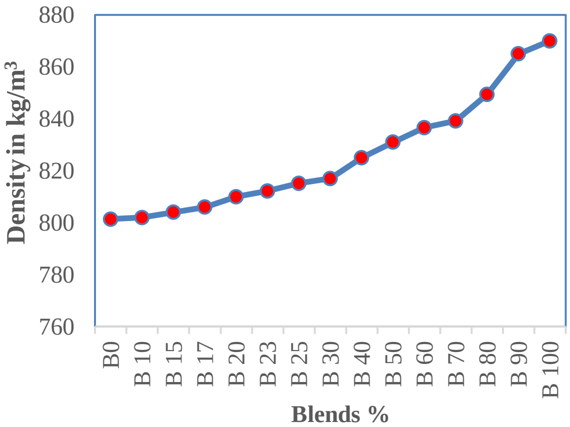

Fig.5. Variation of density with pupae biodiesel-diesel blends

Figure 5 shows the variation of density for various percentages of Pupae Biodiesel blend ratio. From the graph as the percentage of Pupae Biodiesel increases Density of the biodiesel is increased and very high when compared with diesel.

2) Kinematic Viscosity of pupae biodiesel-diesel blends:

Figure 6 shows the variation of Kinematic Viscosity for various percentages of Pupae Biodiesel blend ratio. From the graph as the percentage of Pupae Biodiesel increases, the kinematic viscosity is increases and Kinematic viscosity 100% biodiesel is 3.10cSt which is higher than the diesel having a value of 2.9 cSt.

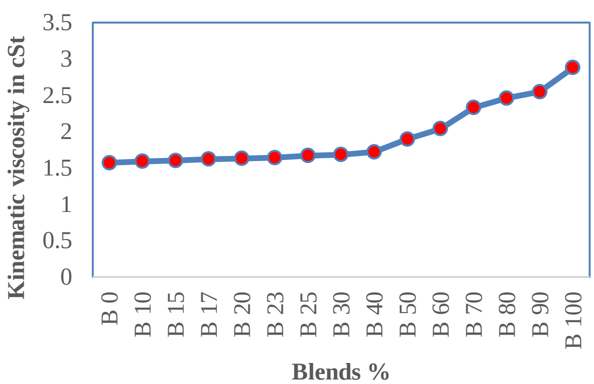

Fig.6. Variation of Kinematic Viscosity with pupae biodiesel-diesel blends

3) Saponification Value pupae biodiesel-diesel blends:

Figure 7 shows the variation of Saponification for various percentages of Pupae Biodiesel blends. From the graph as the percentage of Pupae Biodiesel increases, the Saponification value increases i.e., the amount (mg) of alkali required to saponify a definite quantity (1g) of oil is increased.

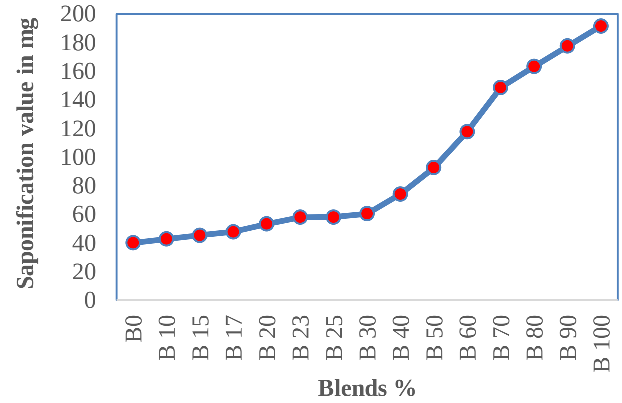

Fig.7. Variation of Saponification with pupae biodiesel-diesel blends

4) Calorific value pupae biodiesel-diesel blends:

Figure 8 shows the variation of calorific value for various percentages of Pupae Biodiesel blends. From the graph, the calorific value of B100 is 34.73 MJ/kg, which is lower than the diesel having a value of 44 MJ/kg. The calorific value of the biodiesel decrease with increases in the biodiesel blends.

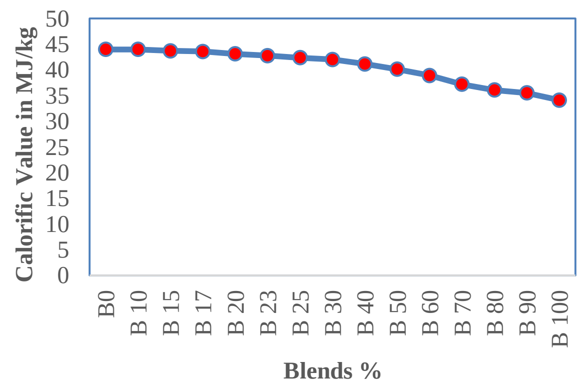

Fig.8. Variation on calorific value of pupae biodiesel-diesel blends

5) Flash and fire point of pupae biodiesel-diesel blends:

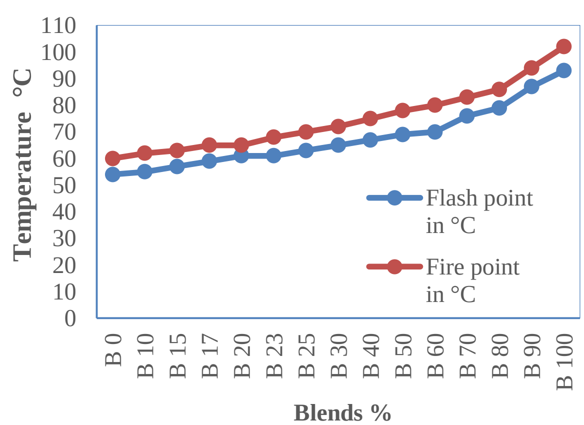

Fig.9. Variation of Flash and fire point with pupae biodiesel-diesel blends

Figure 9 shows the variation of flash and fire points for various percentages of Pupae Biodiesel blend ratio. From the graph as the percentage of Pupae Biodiesel increases the flash and fire points increases i.e. the flash and fire points of diesel is lesser when compared to Pupae Biodiesel and its blends.

6) Cloud and Pour point of pupae biodiesel-diesel blends:

Figure 10 shows the variation of Cloud and Pour points for various percentages of Pupae Biodiesel blend ratio. From the graph as the percentage of Pupae Biodiesel in blend ratio increases, the Cloud and Pour points increases.

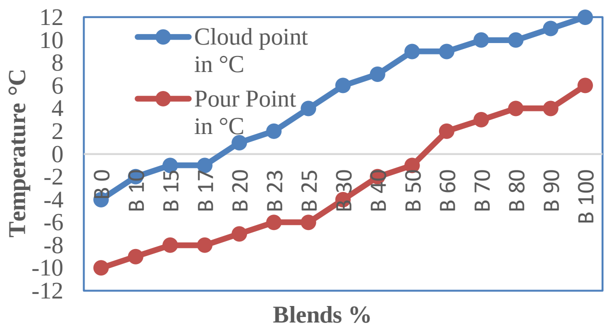

Fig.10. Variation of Cloud and Pour Point with pupae biodiesel-diesel blends

7) PH Value of pupae biodiesel-diesel blends:

Figure 11 shows the variation of pH for various percentages of Pupae Biodiesel blends. From the graph as the percentage of Pupae Biodiesel increases, the pH value decreases.

V. CONCLUSIONS OF PRESENT WORK

The production of biodiesel from pupae oil is the new way to meet the demand of fuel consumption as well as utilize the pupae oil efficiently. The pupae contains high percentage of oil 30-40%. This can be converted into biodiesel. All of the parameters determined for the methyl ester (biodiesel) of the Pupae oil meet the ASTM standard. Properties obtained for blends such as B15, B17, B20, B23, and B25were best as per the ASTM Standard.

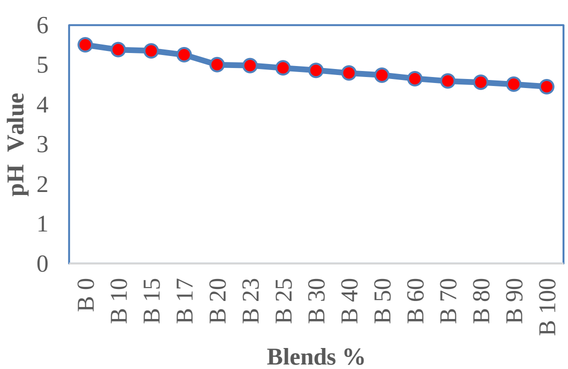

Fig.11. Variation of PH Value with pupae biodiesel-diesel blends

REFERENCES

[1]. F. Halek, A. Kavousi, and M. Banifatemi.Biodiesel as an Alternative Fuel forDiesel Engines; World Academy of Science, Engineering and Techpplogy.Vol. 3, pp. 9, 2009.
[2]. ManojSarma, MausumiGanguly. Production of high quality biodiesel from desilkedmugapupae.Vol. 4, pp. 40-45. 2016.
[3]. Mustafa Balat, HavvaBalat. Progress in biodiesel processing. Applied Energy. Vol. 2 Pp. 87,2010.
[4]. M. Sharma and M. Ganguly. Attacus ricinii (Eri) PupaeOil as an AlternativeFeedstock for the Production of Biofuels. InternationalJournal of Chemical and Environmental Engineering. , Vol. 2, Pp.2, 2011.
[5]. Angelo C. Pintoa, Lilian L. N. Guarieiroa, Michelle J. C. Rezendea, Núbia M. Ribeiroa, Ednildo A. Torresb, Wilson A. Lopesc, Pedro A. de P. Pereirac and Jailson B. de Andrade.Biodiesel: An Overview. Braz. Chem. Soc., Vol. 16, Pp.6.
[6]. S.H.Manjunath, P.SankaranKutty (Sept 2008). Performance of silkworm pupaoil and methyl ester and diesel fuel blends in IC engine. International journal ofApplied Engineering Researcf.Vol.3.2005.
[7]. M.C.Nadeesha, B. Gangadhara and J.K. Manissery.Silkworm Pupae oil andsardine oil as an addition energy source in the diet of common crap, cyprinuscarpio. Asian fisheries science.1999.
[8]. SupanidaWinitchai, AranyaMappsroi and JiradejMappsroi. Effect of nativeThai silk varieties (Bombyxmori L.) and extraction method on chemical compositions of silkworm oil for food and cosmetics applications. 2011.
[9]. Shashi Kumar Jain, Sunil Kumar, and AlokChaube. Technical Sustainability ofBiodiesel and Its Blends with Diesel in C.I. Engines: A Review. International Journalof Chemical Engineering and Applications, Vol. 2, pp. 2, 2011.
[10]. Ulf Schuchardt, Ricardo Sercheli, and RogerioMatheus Vargas. Transesterification of Vegetable Oils. A Review. Journal of the Brazilian ChemicalSociety. Vol.9. 1998.
[11]. M. Canakci, J, Van Gerpen. Biodiesel Production from Oils And Fats With High Free Fatty Acids. American Society of Agricultural Engineers. Vol. 44, pp. 1429–1436. 2001.
[12]. Meridith L. Bartley &Wiebke J. Boeing. pH effects on growth and lipid accumulation of the biofuel microalgae Nannochloropsissalina and invading organisms.SpringerScience+Business Media Dordrecht. 2013.
[13]. PriteePurohit, Sanjay Gaikwad, RavirajGurav.Properties and specifications of biodiesel and there influence on performance of engine: A Review. I-cort.2012.
[14]. Oliveira L. E, Da Silva M. L, C. P. Relationship between cetane number and calorific value of biodiesel from Tilapia visceral oil blends with mineral diesel. International Conference on Renewable Energies and Power Quality. 2013.
[15]. Thiago de O, Macedo, Roberto G. Pereira Viscosity of Vegetable Oils and Biodiesel and Energy Generation.World Academy of Science. Vol. 7, pp. 5, 2013.