# Storage Studies on Plant Oils and Their Methyl Esters

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## ABSTRACT

Esters of plant oils are preferred to parent oils if used as fuels in diesel engines because esterification reduces the viscosity of plant oils and makes it comparable to that of diesel. The present work mainly deals with the effect of storage time on the quality of plant oils and their esters with respect to mainly FFA content, viscosity and change in weight. The study was carried out for a period of one and a half-year. Maximum change in FFA content (%) was observed in case of linseed oil ester followed by sunflower oil ester and rice bran oil ester. Minimum change was observed in the case of Jatropha curcas oil ester. In all the four esters, the increase in FFA content (%) after one year was found to be below the BIS requirements. Initially all the four plant oil esters had comparable viscosity values. In case of linseed oil ester and sunflower oil ester, the increase in viscosity was 1.6 times after a storage period of six months whereas in case of rice bran oil ester and Jatropha curcas oil ester, the increase was 1.4 and 1.3 times respectively. During storage, linseed oil ester, sunflower oil ester and rice bran oil ester showed increase in weight indicating absorption of moisture or reaction with oxygen in air. However, in case of Jatropha curcas oil ester, the increase in weight was negligible. The effect of selected plant oil ester on various engine parts (metallic and non-metallic) was also studied. No significant change in weight of metal components was observed during contact period of two months (i.e. components kept dipped in ester for two months) in any of the four esters. In case of non-metallic components, signficant changes were observed in the rubber parts during the contact period of two months in all the four plant oil esters.

Keywords: Methyl ester, Plant oil, Storage, Viscosity, Bio-diesel, Free fatty acids

## INTRODUCTION

Self-reliance in energy is very important for the development of a nation. With the present state of energy in India, the country is unable to meet the demands of the people. We are dependent on petroleum fuels for transportation and for operating agricultural machinery. Indeed, we have to import these to fulfil the demands of the people. The availability of petroleum fuels is under threat. Scientists world over are on the look out for alternate sources of fuels. Research work is in progress on many biomass-based alternate fuels such as alcohol (Bandel, 1977; Holmer, 1977), producer gas (Singh *et al*., 1997), biogas (Dass and Prasad, 1978; Mehta *et al*., 1980) and plant oil fuel (Shyam, 1984). Amongst these, plant oil fuelare considered very good alternate fuel for CI engines. If the engine run on neat plant oils for longer duration, it results in lot of carbon deposits on engine parts. The major drawback with the neat plant oils as fuels is their high viscosity (Ryan *et al.*, 1982). This constraint can be overcome by the esterification of plant oils, which gives plant oil esters commonly known as bio-diesels. Lot of work has been conducted at PAU, Ludhiana on preparation of bio-diesels from plant oils; their characterisation and use as alternate fuel in existing compression ignition engines without any modification (Verma *et al.*, 1998; Gupta, 1994; Sangha *et al.*, 2000). Promising results have been obtained in running of CI engines on biodiesels. Studies have also been conducted on the long term running of CI engines using these fuels.

Little information is available on the shelf life of these plant oil esters. The present study was thus undertaken to find the effect of storage time on the quality of plant oils and their esters in terms of changes in the viscosity and the free fatty acid (FFA) values. The effect of plant oil esters on the metallic and non-metallic engine components has also been studied.

## MATERIALS AND METHODS

Esters of four crude plant oils namely, linseed, Jatropha curcas, rice bran and sunflower were prepared.

### Esterification of oil

Esterification was done using a simple and inexpensive farm level method reported by Gupta (1994). For each test, 100 g of oil (heated to 60°C) was reacted with alkaline methanol (a homogeneous mixture prepared by dissolving 1 g of NaOH pellets in 20 ml of methanol). Stirred the oil-alkaline methanol mixture for 5-10 minutes and allowed the glycerol to settle for 2 hours. Glycerol separation was effected by using a separating funnel. The ester collected was given three washings with water to remove excess of alkali, if any. The washed ester was heated to evaporate the traces of moisture left. Percentage of oil converted to ester was measured by the modified method of Sangha *et al.* (2000).

### Free fatty acid (FFA) estimation

FFA estimation in the sample was done by the method as suggested by McKillican (1966).

### Estimation of kinematic viscosity

Redwood Viscometer No.1 (Toshniwal make) was used for measurement of kinematic viscosity of the samples. This apparatus was based on the principle of measuring the time of gravity flow (in seconds) of a fixed volume (50 ml.) of fluid through a specified hole made in an agate piece (as per IP 70/62 issued by Institute of Petroleum, London). The apparatus could be used for flow times between 30 and 2000 seconds. Each test was replicated three times. The experiment was performed at 38°C. Kinematic viscosity in centistokes (cS) was calculated from the time units by the following formula:

$$Vk = 0.26\,t - 179/t, \quad \text{when } 34 < t < 100$$

and

$$Vk = 0.24\,t - 50/t, \quad \text{when } t > 100$$

Where,

$Vk$ = kinematic viscosity in centistokes, cS
$t$ = time for flow of 50 ml of sample, seconds

Weight gain studies

In order to study the interaction of oils and ester with atmospheric moisture or air, the samples (oils and esters) were stored in plastic containers and were weighed at regular time intervals (monthly) for a year.

Effect of esters on engine components

Since the engine was run on plant oil esters, it was considered desirable to study the effect of various plant oil esters on the wear and tear of various engine components. This effect was studied in terms of the changes that took place in different components (e.g. change in shape, colour, diameter, thickness, weight, and length etc. depending upon the type of component) during storage.

The metallic components chosen for study were copper washer, aluminium washers, and piston rings. Non-metallic components chosen for the study were rubber washers, plastic pipes and gaskets. The components were kept dipped in the respective plant oil esters for two months, and the parameters were measured at regular intervals.

Results and discussion

The results obtained on various aspects are presented and discussed here under different sub-heads.

Effect of storage time on FFA content of plant oils and their esters

The quality of esters and oils was assessed in terms of presence of free fatty acids (FFA), because at higher temperature, the free fatty acids are known to react with metals like zinc, lead, manganese, cobalt, tin etc. This could lead to increased engine wear. (Pryde, 1982; Romano, 1982).

The study was carried out for a period of one and a half-year and the results are shown in Table 1and Fig 1. It was observed that there was continuous increase in FFA content of all the oils and their esters with storage time. Among the oils, Jatropha curcus oil had the highest increase in FFA (1.41 to 3.50) followed by rice bran oil (0.56 to 2.48), sunflower oil (0.70 to 2.21) and linseed oil (0.38 to 1.72). Among the esters, the maximum change in FFA content was observed in case of linseed oil ester (0.00 to 0.70) followed by sunflower oil ester and rice bran oil ester.

In all the four esters, the FFA after one year of storage was found to be below the BIS recommendations value of 0.5. However, after one and a half-year, the FFA content of linseed oil ester, sunflower oil ester and rice-bran oil ester crossed the BIS recommended levels. In case of Jatropha curcas oil (extracted locally) ester, the increase in FFA content after one and a half-year was still much below the BIS levels. However, all the four esters had significantly lower FFA content compared to their respective oils.

Percent increase over the first non zero value was also determined and presented in Table 1(b). Although, the absolute increase in FFA of oils was quite high compared to that of esters but the present increase in FFA was found to be more in case of esters compared to the oils. In case of oils, maximum percent increase in FFA was observed in case of linseed oil followed by rice bran oil and sunflower oil. But in case of esters, the maximum percent increase in FFA was obtained in case of rice bran oil ester followed by linseed oil ester and sunflower oil ester.

On the whole, it becomes clear that esters have better storability compared to the oils as far as FFA increase is concerned.

Table 1a. Effect of storage time on the free fatty acid content (%) of plant oils and their bio-diesels**.**

| No. of storage days | Lin-seed oil (LSO) | Lin-seed oil ester (LSE) | Sun-flower oil (SFO) | Sun-flower oil ester (SFE) | Jatropha curcas oil (JO)* | Jatropha curcas oil ester (JE)* | Rice-bran oil (RBO)** | Rice-bran oil ester (RBE)** | Diesel (D) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.38 | 0.00 | 0.70 | 0.00 | 1.41 | 0.00 | 0.56 | 0.00 | 0.00 |
| 30 | 0.52 | 0.00 | 0.85 | 0.00 | 1.41 | 0.00 | 0.56 | 0.00 | 0.00 |
| 60 | 0.64 | 0.00 | 0.98 | 0.00 | 1.55 | 0.00 | 0.71 | 0.07 | 0.00 |
| 90 | 0.68 | 0.14 | 1.21 | 0.14 | 1.55 | 0.00 | 0.71 | 0.07 | 0.00 |
| 120 | 0.70 | 0.14 | 1.41 | 0.14 | 1.55 | 0.14 | 0.71 | 0.14 | 0.00 |
| 150 | 0.81 | 0.14 | 1.41 | 0.14 | 1.69 | 0.14 | 1.41 | 0.14 | 0.00 |
| 180 | 0.85 | 0.28 | 1.41 | 0.14 | 1.69 | 0.14 | 1.41 | 0.14 | 0.00 |
| 210 | 0.99 | 0.28 | 1.55 | 0.14 | 1.83 | 0.14 | 1.55 | 0.14 | 0.00 |
| 240 | 1.27 | 0.28 | 1.55 | 0.28 | 1.83 | 0.14 | 1.69 | 0.28 | 0.00 |
| 270 | 1.41 | 0.35 | 1.55 | 0.28 | 2.11 | 0.14 | 1.83 | 0.28 | 0.14 |
| 300 | 1.41 | 0.35 | 1.55 | 0.28 | 2.39 | 0.28 | 2.11 | 0.28 | 0.14 |
| 330 | 1.49 | 0.49 | 1.69 | 0.28 | 3.10 | 0.28 | 2.11 | 0.28 | 0.14 |
| 360 | 1.55 | 0.49 | 2.11. | 0.42 | 3.10 | 0.28 | 2.39 | 0.42 | 0.14 |
| 390 | 1.59 | 0.50 | 2.11 | 0.42 | 3.10 | 0.28 | 2.39 | 0.42 | 0.14 |
| 420 | 1.62 | 0.54 | 2.11 | 0.42 | 3.20 | 0.28 | 2.39 | 0.42 | 0.14 |
| 450 | 1.68 | 0.61 | 2.18 | 0.42 | 3.20 | 0.28 | 2.42 | 0.42 | 0.14 |
| 480 | 1.70 | 0.68 | 2.20 | 0.56 | 3.45 | 0.28 | 2.42 | 0.50 | 0.14 |
| 510 | 1.72 | 0.70 | 2.21 | 0.56 | 3.50 | 0.28 | 2.48 | 0.50 | 0.14 |

***** Oil got extracted locally from purchased seeds
****** Physically refined oil

Table 1b Effect of storage time on the percent increase in free fatty acid content (%) of plant oils and their bio-diesels over first non zero value

| No. of storage days | (LSO) Lin-seed oil | (LSE) Lin-seed oil ester | (SFO) Sun-flower oil | (SFE) Sun-flower oil ester | (JO)* Jatropha curcas oil | (JE)* Jatropha curcas oil ester | (RBO)** Rice- bran oil | (RBE)** Rice- bran oil ester | (D) Diesel |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 36.8 | - | 21.4 | - | 0.0 | - | 0.0 | 0.0 | - |
| 60 | 68.4 | - | 40.0 | - | 9.9 | - | 26.8 | 0.0 | - |
| 90 | 78.9 | * | 72.9 | * | 9.9 | * | 26.8 | 0.0 | - |
| 120 | 84.2 | 0.0 | 101.4 | 0.0 | 9.9 | - | 26.8 | 100.0 | - |
| 150 | 113.2 | 0.0 | 101.4 | 0.0 | 19.9 | 0.0 | 151.8 | 100.0 | - |
| 180 | 123.7 | 100.0 | 101.4 | 0.0 | 19.9 | 0.0 | 151.8 | 100.0 | - |
| 210 | 160.5 | 100.0 | 121.4 | 0.0 | 29.8 | 0.0 | 176.8 | 100.0 | - |
| 240 | 234.2 | 100.0 | 121.4 | 100.0 | 29.8 | 0.0 | 201.8 | 300.0 | - |
| 270 | 271.1 | 150.0 | 121.4 | 100.0 | 49.6 | 0.0 | 226.8 | 300.0 | * |
| 300 | 271.1 | 150.0 | 121.4 | 100.0 | 69.5 | 100.0 | 276.8 | 300.0 | 0.0 |
| 330 | 292.1 | 250.0 | 141.4 | 100.0 | 119.9 | 100.0 | 276.8 | 300.0 | 0.0 |
| 360 | 307.9 | 250.0 | 201.4 | 200.0 | 119.9 | 100.0 | 326.8 | 500.0 | 0.0 |
| 390 | 318.4 | 257.1 | 201.4 | 200.0 | 119.9 | 100.0 | 326.8 | 500.0 | 0.0 |
| 420 | 326.3 | 285.7 | 201.4 | 200.0 | 127.0 | 100.0 | 326.8 | 500.0 | 0.0 |
| 450 | 342.1 | 335.7 | 211.4 | 200.0 | 127.0 | 100.0 | 332.1 | 500.0 | 0.0 |
| 480 | 347.4 | 385.7 | 214.3 | 300.0 | 144.7 | 100.0 | 332.1 | 614.3 | 0.0 |
| 510 | 352.6 | 400.0 | 215.7 | 300.0 | 148.2 | 100.0 | 342.9 | 614.3 | 0.0 |

- FFA values zero.
* First non-zero value obtained.

Effect of storage time on viscosity of plant oils and their esters

Viscosity is one of the major constraints for the use of plant oils as engine fuel (Ryan *et al.*, 1982). Hence, study was undertaken to find out the effect of storage time on viscosity of all the four selected plant oils and their esters. The initial viscosity values of all the esters were comparable. The study was conducted for 210 days. Absolute values of viscosities are given in Table 2 (a) and Fig 2. It is clear from the table that viscosity of all the oils and their esters increased continuously with storage time. Absolute increase in viscosity was higher in case of oils compared to their esters. However, present increase in viscosity was more in case of esters. In case of linseed oil ester and sunflower oil ester, the viscosity values increased by 63.5% and 56.8% respectively (Table 2b) during the storage period of 210 days, whereas in case of rice bran oil ester and Jatropha curcas oil ester, the increase was 46.8% and 34.5% respectively.

Table 2a. Effect of storage time on the viscosity (cS) of plant oils and their bio-diesels

| No of days | Lin-seed oil (LSO) | Lin-seed oil ester (LSE) | Sun-flower oil (SFO) | Sun-flower oil ester (SFE) | Jatropha curcas oil (JO)* | Jatropha curcas oil ester (JE)* | Rice-bran oil (RBO)** | Rice - bran oil ester (RBE)** | Diesel (D) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 31.54 | 7.72 | 43.16 | 8.24 | 44.86 | 7.37 | 54.98 | 7.72 | 5.55 |
| 15 | 32.36 | 7.72 | 43.65 | 8.75 | 45.94 | 7.72 | 55.07 | 7.77 | 5.92 |
| 30 | 35.18 | 8.07 | 43.89 | 8.75 | 46.78 | 8.07 | 55.22 | 8.10 | 5.92 |
| 45 | 35.25 | 8.41 | 44.13 | 10.73 | 46.78 | 8.07 | 58.67 | 8.35 | 6.00 |
| 60 | 35.67 | 9.91 | 46.06 | 10.89 | 46.78 | 8.56 | 61.25 | 8.98 | 6.10 |
| 90 | 36.64 | 10.08 | 46.78 | 11.05 | 47.27 | 9.42 | 65.33 | 9.75 | 5.90 |
| 120 | 37.60 | 11.05 | 48.23 | 11.37 | 47.99 | 9.56 | 68.95 | 10.12 | 6.26 |
| 150 | 43.65 | 11.37 | 49.92 | 11.37 | 49.20 | 9.72 | 69.98 | 10.73 | 6.20 |
| 180 | 43.89 | 11.84 | 51.01 | 12.62 | 54.02 | 9.91 | 71.1 | 10.97 | 6.10 |
| 210 | 44.37 | 12.62 | 51.37 | 12.92 | 54.02 | 9.91 | 71.35 | 11.33 | 6.26 |

***** oil got extracted locally from purchased seeds.
****** parboiled rice bran oil.

Table 2b Effect of storage time on percent increase in viscosity (cS) of plant oils and their bio-diesels

| | (LSO) | (LSE) | (SFO) | (SFE) | (JO)* | (JE)* | (RBO)** | (RBE)** | (D) |
|---|---|---|---|---|---|---|---|---|---|
| No. of days | Lin-seed oil | Lin-seed oil ester | Sun-flower oil | Sun-flower oil ester | Jatropha curcas oil | Jatropha curcas oil ester | Rice- bran oil | Rice- bran oil ester | Diesel |
| 15 | 2.6 | 0.0 | 1.1 | 6.2 | 2.4 | 4.7 | 0.2 | 0.6 | 6.7 |
| 30 | 11.5 | 4.5 | 1.7 | 6.2 | 4.3 | 9.5 | 0.4 | 4.9 | 6.7 |
| 45 | 11.8 | 8.9 | 2.2 | 30.2 | 4.3 | 9.5 | 6.7 | 8.2 | 8.1 |
| 60 | 13.1 | 28.4 | 6.7 | 32.2 | 4.3 | 16.1 | 11.4 | 16.3 | 9.9 |
| 90 | 16.2 | 30.6 | 8.4 | 34.1 | 5.4 | 27.8 | 18.8 | 26.3 | 6.3 |
| 120 | 19.2 | 43.1 | 11.7 | 38.0 | 7.0 | 29.7 | 25.4 | 31.1 | 12.8 |
| 150 | 38.4 | 47.3 | 15.7 | 38.0 | 9.7 | 31.9 | 27.3 | 39.0 | 11.7 |
| 180 | 39.2 | 53.4 | 18.2 | 53.2 | 20.4 | 34.5 | 29.3 | 42.1 | 9.9 |
| 210 | 40.7 | 63.5 | 19.0 | 56.8 | 20.4 | 34.5 | 29.8 | 46.8 | 12.8 |

The viscosity variation among the different esters could be attributed to the structural variations (variations in the fatty acid composition, Table 3) of the esters. The increase in viscosity could be due to auto oxidation and polymerisation. The more the unsaturation, the more is the polymerisation.

Table 3. Fatty acid composition (%) of selected plant oils.

| Fatty acids | Lin- seed oil | Sun flower oil | Jatropha curcas oil* | Rice bran oil** |
|---|---|---|---|---|
| Palmitic acid (16:0) | .7.35 | 4.65 | 13.05 | 19.66 |
| Olic acid (18:1) | 38.27 | 61.07 | 45.59 | 50.88 |
| Linolenic acid (18:2) | 8.85 | 23.83 | 28.86 | 27.21 |
| Linolenic acid (18:3) | 44.41 | 1.49 | 5.99 | 1.37 |
| Arachidic acid (20:0) | 0.99 | 1.44 | 1.12 | 0.71 |
| Behenic acid (22:0) | 0.13 | 7.53 | 5.39 | 0.17 |

Effect of storage time on weight gain of selected plant oils and their esters

Effect of storage time on the weight gain of plant oils and their esters was studied by storing each sample in two different plastic containers - one fully filled (FF) with sample and the other half-filled (HF) with sample. As evident from Table 4, in case of linseed oil, the weight gain was higher in the half-filled container as compared to fully filled container. In case of half-filled container, an elastic substance known as linoxygen, which is formed by the reaction of oil with atmospheric oxygen (Bhatia, 1983), got deposited at the rim of the container. Whereas the deposit of linoxygen was negligible in the case of fully filled containers. The linoxygen deposits were the minimum in the samples stored uninterrupted (those in which the lid was not opened frequently) compared to those whose lids were opened at regular intervals.

In case of linseed oil, the lid of the plastic container was difficult to open after 15 days of storage, indicating that vacuum had been created in the container, which indicated the reaction of the sample with air. No such vacuum problem was observed in any other sample stored.

No deposition of linoxygen was observed in case of linseed oil ester. In case of ester, the weight gain was similar in fully filled and half-filled containers.

In case of sunflower oil and sunflower oil ester, the weight gain was more in half-filled (HF) container as compared to the fully filled container (FF). The increase in weight was negligible in case of Jatropha curcas oil (JO) and its ester (JE), both in the FF and in the HF containers. This could be attributed to its fatty acid composition (Table 4). In case of rice bran oil (RBO) and its ester (RBE), the study was carried out for a period of six months only. Surprisingly, in case of RBO, the increase in weight was more in case of fully filled containers than half-filled ones. Similar change was observed in case of RBE also.

In order to check whether the weight gain was due to moisture absorption or due to reaction with air, the samples were simultaneously stored in glass beakers, which could be heated at 100°C to remove the moisture. Initially the beakers were heated to get a constant weight i.e. to have moisture free samples. After an interval of one year, and one and half year, these were weighed again to find the increase in weight (as was observed in case of plastic containers). The beakers were then again heated at 100° C to determine the presence of moisture. It was observed that on heating, there was decrease in the weight of the sample but this decrease was lesser than the total increase in weight due to storage. Thus, the increase in weight could partly be due to moisture absorption and partly due to reaction with air. But in the case of linseed oil, the decrease in weight upon heating at 100°C was negligible indicating that no water was absorbed by the sample during storage. As such, the increase in weight due to storage may be mainly due to reaction with air.

Effect of plant oil ester on metallic components of engine

The metallic components chosen for study were copper washers, aluminium washers and piston rings. Various parameters (depending upon the type of the part) were studied such as diameter, thickness, weight and length. Changes in these parameters were measured. The study was carried out for two months with observations recorded at regular interval. No significant change was observed in any of the parameters studied.

Table 4. Effect of storage time on the weight gain, in grams, of plant oils and their bio-diesels

| No. of days | LSO FF | LSO HF | LSE FF | LSE HF | SFO FF | SFO HF | SFE FF | SFE HF | JO FF | JO HF | JE FF | JE HF | D FF | D HF | RBO FF | RBO HF | RBE FF | RBE HF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 91.07 | 44.20 | 86.88 | 44.06 | 87.96 | 44.41 | 85.70 | 42.86 | 88.69 | 44.19 | 85.09 | 41.86 | 83.22 | 41.53 | 87.17 | 44.06 | 86.38 | 43.07 |
| 30 | 91.07 | 44.28 | 87.07 | 44.23 | 87.98 | 44.42 | 85.76 | 42.89 | 88.73 | 44.21 | 85.09 | 41.88 | 82.60 | 41.21 | 87.20 | 44.09 | 86.39 | 43.08 |
| 60 | 91.27 | 44.62 | 88.31 | 46.31 | 88.09 | 44.49 | 85.90 | 42.97 | 88.84 | 44.27 | 85.10 | 41.91 | 81.66 | 40.61 | 87.23 | 44.13 | 86.40 | 43.09 |
| 90 | 91.34 | 44.89 | 89.23 | 47.26 | 88.13 | 44.50 | 86.30 | 43.49 | 88.84 | 44.28 | 85.09 | 41.92 | 81.10 | 40.22 | 87.28 | 44.13 | 86.44 | 43.11 |
| 120 | 91.47 | 45.29 | 90.39 | 47.83 | 88.19 | 44.56 | 86.30 | 44.53 | 88.86 | 44.33 | 85.10 | 41.93 | 80.67 | 40.00 | 87.30 | 44.14 | 86.45 | 43.10 |
| 150 | 91.52 | 45.51 | 90.87 | 48.03 | 88.20 | 44.58 | 86.33 | 44.65 | 88.86 | 44.33 | 85.10 | 41.93 | 80.82 | 39.95 | 87.57 | 44.34 | 86.69 | 43.24 |
| 180 | 91.54 | 45.65 | 90.92 | 48,35 | 88.24 | 44.58 | 86.36 | 44.74 | 88.87 | 44.34 | 85.10 | 41.93 | 80.44 | 39.88 | - | - | - | - |
| 210 | 91.56 | 45.89 | 91.08 | 48.54 | 88.26 | 44.59 | 86.49 | 44.82 | 88.88 | 44.35 | 85.12 | 41.94 | 80.36 | 39.78 | - | - | - | - |
| 240 | 91.58 | 45.99 | 91.24 | 48.68 | 88.27 | 44.63 | 86.53 | 44.96 | 88.89 | 44.37 | 85.12 | 41.94 | 80.22 | 39.62 | - | - | - | - |
| 270 | 91.62 | 46.02 | 91.45 | 48.80 | 88.30 | 44.75 | 86.58 | 45.10 | 88.90 | 44.39 | 85.13 | 41.94 | 80.15 | 39.59 | - | - | - | - |
| 300 | 91.66 | 46.24 | 91.62 | 48.86 | 88.32 | 44.80 | 86.64 | 45.38 | 88.92 | 44.44 | 85.14 | 41.95 | 80.10 | 39.48 | - | - | - | - |
| 330 | 91.68 | 46.34 | 91.89 | 48.97 | 88.32 | 44.87 | 86.69 | 45.76 | 88.96 | 44.56 | 85.14 | 41.96 | 80.06 | 39.33 | - | - | - | - |
| 360 | 91.77 | 46.94 | 92.14 | 49.06 | 88.35 | 44.95 | 86.34 | 45.91 | 89.29 | 44.82 | 85.15 | 41.96 | 79.70 | 39.00 | - | - | - | - |

FF - Fully filled, HF - Half filled
LSO - Linseed oil, LSE - Linseed bio-diesel
SFO - Sunflower oil, SFE - Sunflower bio-diesel
JO - Jatropha curcas oil, JE - Jatropha curcas bio-diesel
RBO - Rice bran oil, RBE - Rice bran bio-diesel
D - Diesel fuel

Diesel was taken as control in case of all these components. No change in the dimensions was observed. However, after 1-1/2 months, the colour of the linseed oil ester (LSE) containing copper washer changed from golden yellow to red. After 21 days, the colour of the sun flower oil ester containing copper washer changed from golden yellow to green. After 60 days, a peach coloured precipitate layer was found deposited on the copper washer in case of sunflower oil ester (SFE). The unsaturated fatty acids present in the LSE and SFE (as evident from Table 3) might have changed the oxidation state of dissolved copper ions (Pshinger *et al.*, 1982)

Effect of plant oil ester on non-metallic components of engine

The non-metallic components chosen for study were rubber washer, plastic pipes and gaskets. Diesel was taken as control. The study was carried out for two months. Among the non-metallic components, maximum changes were observed in case of rubber washers followed by insignificant changes in case of plastic pipes. No changes were observed in case of gaskets. The results for rubber washer are given in Table 5.

In case of rubber washer dipped in diesel, which was taken as control, increase in thickness, length and weight of rubber washer was observed to be 13%, 12% and 33% respectively after a week.. The change remained the same even after two months. However, the increase in various parameters did not affect the fragility of the rubber. When the rubber washer was dipped in LSE, an increase in various dimensions of the rubber piece was observed. After 21 days of dipping, the increase in various parameters was observed to be thickness (25%), length (33%), width (14%) and weight (100%). It was more as compared to the changes observed in case of rubber washer dipped in diesel. In LSE, the rubber washer became quite fragile. After 30 days of dipping, it got dissolved in the ester. In case of rubber washer dipped in SFE, the changes observed were even more pronounced as compared to that in LSE (as is clear from Table 5) and the washer was dissolved just after 21 days of dipping (Pishinger *et al.*, 1982).

In case of rubber washer dipped in Jatropha curcas oil ester, the changes observed even after 60 days of dipping were less as compared to those in LSE and in SFE (Table 5). The rubber washer got almost dissolved after 90 days of dipping in JE. In RBE, the rubber washer behaved in the same manner as in JE.

Table 5 Changes observed in dimensions of rubber washer dipped in various plant oil esters.

| Dimensions | No.of Days | Diesel | LSE | SFE | JE | RBE |
|---|---|---|---|---|---|---|
| Thickness, mm | 0 | 0.185 | 0.18 | 0.18 | 0.18 | 0.18 |
| | 7 | 0.21 | 0.22 | 0.23 | 0.21 | 0.22 |
| | 21 | 0.21 | 0.23 | 0.25 | 0.21 | 0.22 |
| | 30 | 0.21 | - | - | 0.21 | 0.24 |
| | 45 | 0.21 | - | - | 0.22 | - |
| | 60 | 0.21 | - | - | 0.22 | - |
| Length, mm | 0 | 1.93 | 1.79 | 1.81 | 1.82 | 2.16 |
| | 7 | 1.93 | 2.08 | 2.13 | 2.05 | 2.40 |
| | 21 | 1.94 | 2.39 | 2.51 | 2.07 | 2.50 |
| | 30 | 1.96 | - | - | 2.14 | 2.68 |
| | 45 | 1.97 | - | - | 2.16 | - |
| | 60 | 1.98 | - | - | 2.23 | - |
| Weight, g | 0 | 0.21 | 0.17 | 0.17 | 0.17 | 0.21 |
| | 7 | 0.22 | 0.26 | 0.27 | 0.23 | 0.28 |
| | 21 | 0.22 | 0.36 | - | 0.24 | 0.31 |
| | 30 | 0.22 | - | - | 0.25 | 0.36 |
| | 45 | 0.22 | - | - | 0.27 | - |
| | 60 | 0.22 | - | - | 0.30 | - |
| Width, mm | 0 | 0.39 | 0.43 | 0.35 | 0.35 | 0.35 |
| | 7 | 0.40 | 0.44 | 0.44 | 0.38 | 0.37 |
| | 21 | 0.40 | 0.48 | 0.50 | 0.41 | 0.41 |
| | 30 | 0.41 | - | - | 0.42 | 0.37 |
| | 45 | 0.42 | - | - | 0.43 | - |
| | 60 | 0.42 | - | - | 0.42 | - |

Note: The sign '–' means the rubber washer had dissolved.

## CONCLUSIONS

The following conclusions are drawn:

i) There was a marginal increase in the FFA contents of the methyl esters stored for a period of over one year.

ii) Increase in viscosity was maximum in case of linseed oil ester and sunflower oil esters followed by rice bran oil ester and Jatropha curcas oil ester after a storage period of six months.

iii) A slight weight gain occurred when the plant oil esters were stored for a period of over one year.

iv) There was no significant change in the dimensions of the metallic components coming in contact with the methyl esters. However, the non-metallic components particularly the rubber washer was affected.

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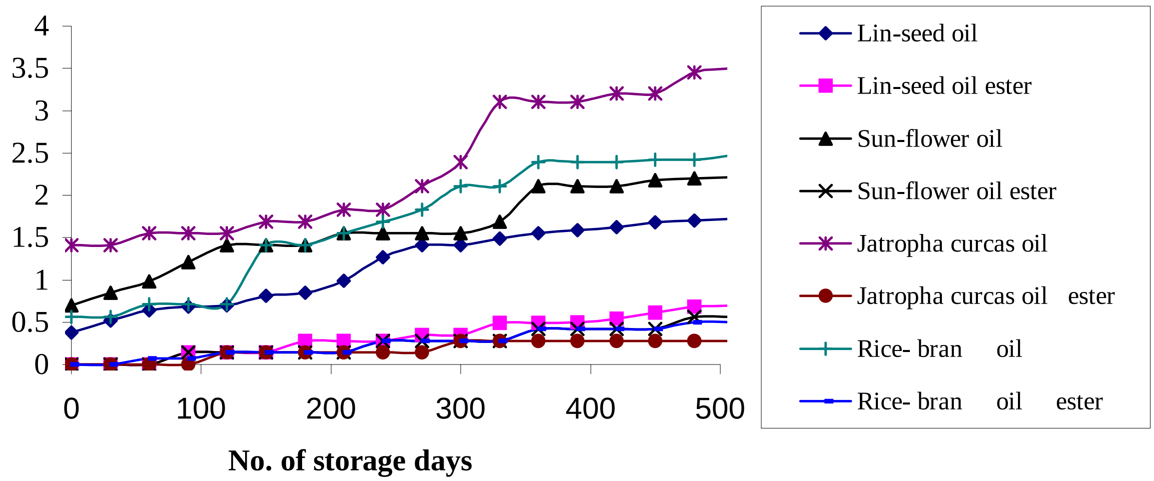


**Fig 1. Effect of storage time on the free fatty acid content (%) of plant oils and their bio-diesels**

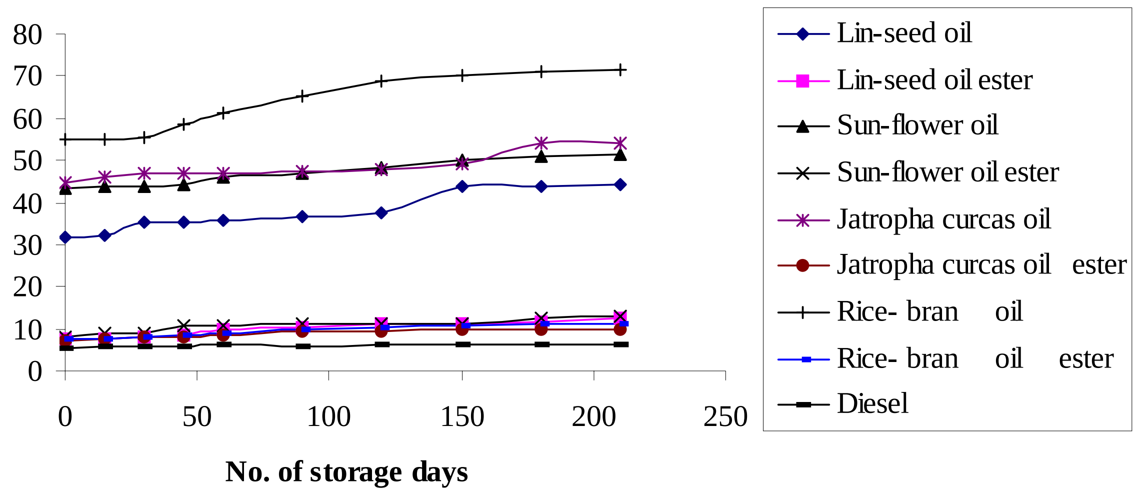


**Fig 2. Effect of storage time on the viscosity (cS) of plant oils and their bio-diesels**