Introduction / background:

The present era relies on fossil fuel combustion to produce their fuels. Fossil fuels are non-renewable sources of energy, and are rapidly depleting. The main source of fuels is by coal at an average 49% of fuels are obtained from burning coal, studies estimated that by the year 2051 coal will be depleted (Bauer et al., 2015). However, fossil fuels combustion leads to the emission of carbon in the environment and the increasing amount of carbon is leading to global warming, world is now looking for new ways to produce fuels in an eco-friendly manner. Biofuels are such one alternative, can be produced by utilizing organic matter derived from plants, animals or microorganisms (Rudolf, 1926). Biofuels are a key factor that can reduce the global warming issue and also meet the rising demand of fuels. Biofuels have been researched upon for a long time and have been modified, thus there are four generations of biofuels (Table 1). Fourth generation which are most researched upon and utilized microalgae for lipid subsequently converted in to biofuels (Yafei et al., 2014).

Keywords: Microalgae, renewable energy Hybrid photobioreactor, Lipid yield, FTIR.

Table 1: Generations of Biofuels

<table>
<thead>
<tr>
<th>GENERATION</th>
<th>TYPE</th>
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<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Agricultural food crops based (e.g. Wheat, sugar etc)</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Agricultural non-food crops (e.g. Wood etc)</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Algal species used for oil production</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Microalgae for lipid based biofuels extraction</td>
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Objectives:

Microalgae are unicellular photosynthetic organisms that assimilate lipids, which can be converted into biofuels. Microalgae help to mitigate carbon dioxide, because of their photosynthetic properties and utilize it to produce lipids. Microalgae biomass is a zero waste generation, as every part of the biomass is utilized to generate other value added products such as Bioethanol, Nutraceuticals, Biofertilizer, Biodiesel and Gasoline (Clayton et al., 2010). Biofuels are being adapted in various countries as alternative fuels (Herve et al., 2011). Scanty research was documented on using Microalgae as feedstock for Biodiesel production. Photobioreactor (PBR) is specially designed for effective cultivation of microalgae, however hybrid PBR have been meagerly researched. Scanty research has been done on tubular type PBR and the various light source tested being of less impact on the growth of microalgae. With the lacunae discussed the present investigation aimed in following objectives.

1. Design and fabrication of hybrid photobioreactor (combing flat plate and tubular type of photobioreactor).
2. Mass cultivation of newly isolated species (Chlorella rotunda) in the indigenously designed photobioreactor.
3. To enhance the yield of biomass and lipid content for biodiesel and other value added products

Methodology:

The present study designed a hybrid PBR (flat plate and tubular) based on both batch and continuous kinetic modules, considering the different design dimensions i.e height, breath, width, diameter of tubular column, surface area and volume Fig. 1.

![Fig 1: CAED design of Continuous Hybrid Photobioreactor. Dimensions: A: Aerator, b1,b2:breath, w1,w2-width, h1,h2:height, v1,v2:valves, H:harvest, L:LED light.](image)

Study utilized LED as the source of artificial blue light to support the growth of microalgae. Initially preserved microalgae culture was revived on BBM plate. The purity and metabolic stability of the revived microalgae was accessed through morphological and microscopic (both light and SEM) observations. The designed and fabricated hybrid PBR was tested for microalgae cultures, in both batch and continuous cultivation process (Turbidostat). Optimized modified Bold's Basal media (BBM) (Mounisha et al., 2015) was used in the present investigation. Further the study compared the growth of microalgae and its biomass yield @ both optimal (PBR cultures) and flask cultures conditions. Further growth kinetics of the microalgae was studied measuring the absorbance at visible range (550nm). Finally lipid
estimation was carried out considering certain time interval for both the cultures (PBR and Flask) colorimetrically and final confirmation of the lipids was down using FTIR analysis.

**Results and Conclusions:**

The results reported that indigenously designed PBR supported exponential growth, and was reported due to the provision of optimal growth conditions provided by the PBR compare to the flask cultures Fig.2.

![Fig. 2: Designed and fabricated PBR with LED light source.](image)

The molecular and phylogenetic analysis revealed that the *microalgae spp* was found to be *Chlorella rotunda*. The lipid estimation reported the lipid concentration 2.4 mg/ml for PBR cultures, was 4 folds higher than the flask cultures (0.24 mg/ml) Fig.3. The doubling time measured was reduced from 63 hrs in shaken flask cultures to 2.88 hrs in first batch PBR. A second batch was done to further reduce the doubling time in PBR cultures providing carbon dioxide a source. In the second batch, doubling time was reduced to 1.5 hrs and the lipid content increased further to 3.7 mg/ml which is 1.5 folds higher than the first batch (2.5mg/ml).

![Lipid Estimation](image)

**Fig 3: Comparison of lipid yield under optimized and un-optimized conditions**

The preset study concludes by reporting the designed and fabricated PBR supported for the mass cultivation of microalgae *Chlorella rotunda*.

**Scope for future work:** The pilot plant studies need to be carried out for the suggested PBR design.