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# Bio-Ethanol Derived from Less Edible Fruit Cultivars of Coorg District (Karnataka) and Parametric Analysis Using IC Engine Fuelled with Bio-Ethanol-Diesel Blends

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**Abstract:** The sustainable production of ethanol from non-edible fruit and their wastes is focused in the current investigation. Bio-ethanol is a fuel ethanol (ethyl alcohol), the same type of alcohol found in alcoholic beverages. It is most often used as a motor fuel, mainly as a bio-fuel additive for gasoline. In the present research study, an attempt has been made to obtain a fuel grade ethanol using fruit samples like, Passion fruit (*Passiflora edulis*L) and Cashew Apple (*Anacardium occidentale*L.) by fermenting them with the help of flocculating yeast (*Saccharomyces cerevisiae,* L*).* As we could obtain 48% alcohol after distillation s, we can envisage that, an optimized concentration of ethanol can be obtained after standardization of the protocol. This bio-ethanol can be used as bio-fuel. As this process is cost effective, much cleaner, eco-friendly and do not yield any toxic residues or gases; so a common man can develop this technique which can able to produce ethanol at industrial level. Therefore, in the present attempts, technological attributes of flocculated Yeast (*Saccharomyces cereviseae*) was employed to enhance its use in alcoholic fermentation, they produce bio-ethanol in the selected fruit cultivars at significant extent in a speed about three to four times greater than the yield reported in the earlier studies. Among the samples evaluated for the yield of ethanol, sample-4 (Passion fruit juice) gave 100% purity of ethanol as compared to standard. The bio-ethanol obtained as a result of fermentation was subjected for the evaluation of Engine performance using single cylinder engine with standard specifications. It revealed a most significant performance with the variable blend of Bio-ethanol and Petroleum diesel (B10-15). Besides, a remarkable reduction in the production of hazardous gases (NOX) with the blends of bio-ethanol (B10-15) was observed. The bio-ethanol produced from non-edible fruit samples was found to be of high quality, which can be utilized as an alternative fuel in the engine system as it meet the ASTM standards with regards to performance and emission parameters especially viscosity and metal content. Hence, a good quality bio-ethanol production form non-edible fruit samples has been justified which can be used further in the industries explicitly by Automobiles and transportation.

**Keywords:** Bio-ethanol, Less Edible Fruit cultivars, Cashew apple, fashion fruit, Yeast, Fermentation, IC Engine, performance, emission parameters.

## INTRODUCTION

The world scenario- the energy requirements are mainly based on fossil fuels. However, these fuel reserves are finite and their exploitation has created serious environmental problems. As a consequence, the demand for alternative renewable sources has been intensified *visa-vis*; the rising demand for energy and raw materials [1]. The possibility and production of green energy (environment friendly) from waste material has played an important role in recent days due to the depletion of non-renewable energy resources [2, 3]. Hence, the biological sources are emerging as most preferred sources that have potential to meet these challenges of sustainability. An increasing number of developed and rapidly developing nations see bio-fuels as a key to reducing reliance on foreign oil, lowering emissions of green house gases (GHG), mainly carbon dioxide ($CO_2$) and methane ($CH_4$), and meeting rural development goals [4, 5, 2, 1, 6].

At present it is overwhelmed by difficulties like decrease in the petroleum fuels extracted from fossil resources, rapid rise in green house gas emissions contributing to global warming, and the lackof potential to meet the ever-increasing energy demands. The attempts made to reduce the impact of these global concerns; bio-ethanol produced from renewable resources like biomass components has created significant interest. In that, Bio-ethanol is found to be most promising fuel which is an alcohol found in alcoholic beverages and it is Alcohol based liquid fuel made from agricultural bio mass Bio-ethanol an important bio-fuel, having high calorific value has the added advantage of being less polluting than most sources of energy that are in use today [7, 8]. It is most often used as motor fuel mainly as bio-fuel additive for gasoline. Ethanol, unlike petroleum, is claimed to be a form of renewable energy that can be produced from agricultural crops such as sugar cane, potato, and corn. Reports available suggest that previous natural substrates for ethanol production via saccharification have included sugarcane bagasse, wheat straw, corn, softwood, fruits etc [9-12].

The Fruit samples are excellent sources of cellulose which can be used for the production of ethanol via saccharification followed by fermentation [13, 14]. Besides, Bio-fuel production from renewable sources is widely considered to be one of the most sustainable alternatives to petroleum sourced fuels and a viable means for environmental and economic sustainability [15, 16, 3].

Coorg, commonly known as Kodagu is the smallest district in Karnataka (INDIA). Kodagu is configured with mountains. Agriculture is the developed sector in Kodagu. The main crops of district are cardamom, pepper, coffee, cinchona, ginger & paddy. Fruits such as limes, baddpulis, oranges, passion fruits, butter fruits, banana, pineapple, fig, gooseberry and sapotas are grown. Now with the exception of orange, lime, and banana cultivation no other fruit is grown economically. Approximately sixty five percent of Kodagu’s geographical area is under tree cover & it is also one of the densely forested districts of India. Kodagu is also regarded as hotspot of biodiversity within Western Ghats as it has diverse kinds of vegetation. As climate is cool throughout the year wine preparation is common in most of the household. Many of them prepare wine in large quantity and sell it. The commonly prepared wines are of goose-berry, passion fruit, grape, pineapple, Cashew apple, lime, rice, betel, ginger, fig, banana etc.

Juice industries of certain fruits, such as passion fruit, grape, pineapple, Cashew apple are grown in almost all local territory of Coorg districts; generate large amounts of waste (peels and seeds) from the crush of tons of fruit to obtain the juice. Thus, there is a great the amount of passion fruit waste that could be processed in ethanol [17].

However, utilization of these fruit materials in production of bio-fuels would be of great environmental and economic benefit as it could reduce the burden on conventional sources of energy and also get rid of the wastes. Hence, the present study has been initiated to evaluate juices extracted from fruit cultivars explicitly, *Passiflora edulis* (L.) and *Anacardium occidentale* (L.) for the production of Bio-ethanol by fermentation using flocculating Yeast (*Saccharomyces cerevisiae*).

## MATERIALS AND METHODS

The study was initiated with baseline survey at different parts of Kodagu district (Karnataka). During the survey, interaction was made with fruit growers and withmany household people who prepare wine and sellas family enterprise. Further, interaction was also extended with commercial wine vendors regarding the present scenario emphasizing on collection of fruit material, processing, preparation of wine and market value of these home-made wine varieties. The first hand information was gathered through semi structured questionnaire.

### Collecting the Fruit Materials

The fruit materials; *Passiflora edulis* (Passion fruit) and *Anacardium occidentale* **(**Cashew Apple**)** used in this study were procured from the local fruit growers of Coorg district, Karnataka (INDIA) during the period; August, 2013 to October, 2014both pre and post-harvest seasons. The plantation of both Passion fruit and Cashew Apple is located along the eastern part in the rural region of Kodagu district. A local-wild variety of cashew apples that did not show prominent cashew-nut attachment; these were selected. Similarly, Yellow & Purple coloured Passion fruits were procured from the cashew orchards by the Farm Manager (Mr. Rauf). The details of both fruit cultivars are briefed hereunder.

### Passion fruit

Passion Fruits (*Passiflora edulis*, L) are commonly grown in cold regions. Passion fruits are abundantly grown in South American countries. The fruits are extensively grown in different parts of Coorg and Malnad Area of Karnataka. These fruits are also grown in Kodaikanal region of Tamil Nadu, Wayanad region of Kerala. Usually, Passion fruits area Yellow & Purple coloured fruits are commonly available in Coorg region (Fig-A).

### Cashew apple fruit

Cashew apples grow from the cashew tree (*Anacardiumoccidentale* L.), which is basically a native exotic plant in Brazil. The largest cashew regions are Brazil, India, Nigeria, Tanzania, Indonesia, and Vietnam. These fruits are grown expansively in specific regions of Coorg district and also Malnad area of Karnataka. Cashew apples are afalse fruits and are physically described as small, hard, pear-shaped green fruit, and when ripened turn red, yellow or orange (Fig -B).

**Processing Fruit cultivars (substrates)**

The fruit samples of *Passiflora edulis* (Passion fruit) and *Anacardium occidentale* (Cashew Apple) were obtained from local growers of Coorg district (Karnataka) as mentioned above. The Passion fruits were washed under running tap water and are peeled off, and are subjected for squashing using Mixer. Squashed fruits are filtered using white cloth. Filtered squash is transferred to plastic barrel. Sugar syrup is added. Potassium Meta bi-sulphite & yeast is added. In other barrel to the same quantity of contents instead of yeast wheat is added. Barrels are kept at room temperature for about 14 days.

In case of Cashew Apples; the fruits were washed twice with distilled water before being prepared for use. The fruit materials were dried in a hot air oven at 65˚C for 24 hours and powdered using a grinder. 50 g of each rind was weighed and utilized as the substrate [18, 19].

**Extraction of Juice from Fruit cultivars**

Passion Fruit Juice (PFJ) and Cashew Apple Juice (CAJ) extraction was done at the Applied Science Laboratory in association with Bhoomigeetha Institute of Research & development (BIRD), Mysore. The whole fruits were washed individually and cut in half. The fruit pieces were then compressed in a fruit processor with a separate pulp collector. Whilst extracting, the PFJ and CAJ were kept cold on ice followed by frozen condition and further was stored at −20∘C for subsequent use [20].

**Physico-Chemical Characterization of Juice extracted from Fruit cultivars**

The juices extracted from both fruit cultivars were subjected for physic-chemical parameters all through the fermentation and the data has been represented in the form of tables respectively. Besides, the parameters such as reducing sugar, pH, Effect of specific gravity, Titration, Concentration of ethanol are continuously monitored during the fermentation.

**Microorganism and Culture media**

*Saccharomyces cerevisiae*was procured from authorized sources, (Azyme Technologies, Bengaluru). This Yeast was cultured on Yeast extract Peptone Dextrose (YPD) at30˚C. The cultures were stored at 4˚C and sub-cultured every 30 days and the same was subjected for flocculation in order to elicit their activation at the time of experiment.

**Preparationof PFJ and CAJ for fermentation**

PFJ and CAJ were prepared, prior to each fermentation by pretreatment, centrifugation and sterilization. Pretreatment involved the addition of 1% (w/v) gelatin powder tothe raw PFJ and CAJ were maintained at 4∘C for 24hrs. This was followed by centrifugation at 3500 rpm for 20min, additionof 2.5 g/L of ammonium sulphate and sterilization at 121∘Cfor 15min. The PFJ and CAJ were sterilized in conjunction with the fermentation vessel [21].

**Fermentation**

**Preparation of Yeast Inocula**

In the study, the Yeast inoculums were prepared in sterilized yeast peptone dextrose (YPD) liquid broth. The composition of YPD in g/L was 10 g yeast extract powder, 20 g peptone powder and 20 g D-glucose. The culture conditions were as follows: (i) volume = 200mL, (ii) temperature = 30∘C, (iii) agitation = 150 rpm, and (iv) duration = 18 hrs. The yeast was activated by extracting the glycerol and re-suspending the pellet in 1mLof YPD broth, and this suspension was added to 50mL of YPD liquid broth. The cell count was increased by sub-culturing followed by flocculation at 10% every 18 hrs from 50mL to 200mL (32). After cultivation, the cell viability was determined and 10% of the initial fermentation volume was used as a starter culture [22, 18, 23].

**Saccharification and its knocking action**

Saccharification is the critical step for bio-ethanol production where complex carbohydrates are converted to simple monomers. Compared to acid hydrolysis, enzymatic hydrolysis requires less energy and mild environment conditions. The processed fruit materials were added to a broth containing yeast extract (5g/l) and peptone (10g/l). The media was autoclaved at $121^0$C and 15 psi pressure for 20 min and Yeast was inoculated under aseptic conditions. The flasks were then incubated at room temperature for a period of 144 hrs.

Subsequent to saccharification, the cultures were autoclaved and filtered using what man No. 1 filter paper. The filtrate was then transferred into 250ml Erlenmeyer flasks, made airtight with cork and autoclaved. The flasks were then aseptically inoculated with 15mlovernight grown S. *cerevisiae* and incubated at room temperature for 96hrs.

Fermentation of Fruit Juice of both *Passiflora edulis* (Passion fruit) and *Anacardium occidentale* (Cashew Apple) was performed with A BIOSTAT Bplus2L MO-O2 fermentor (Sartorius Stedim Systems GmBH, Germany) to produce bio-ethanol. The operating conditions of the batch fermentations are summarized in Table-2. Fermentations were performed in duplicate.

The ethanol produced was determined by Gas Chromatography (Bipolar, 1250 mV, 10 Samp) using a NUCON Gas Chromatograph (5765 EPC) with a flame ionization detector per Sec. The carriergas used was Nitrogen.

**Distillation**

In the current study, the batch distillation method was adopted. The distillation unit consisted of three components: a re-boiler, condenser pipe and a distillate or receiving flask. The filtered samples was transferred into the re-boiler and heated to boil respectively. The vapors started to rise into the still head and passed through condenser pipe. The continuous circulation of cold water around the condenser pipe assisted in cooling the alcohol rich vapors back to liquid state. The condensed liquid enters the still receiver and then collected in the distillate. The distillate was tested for its alcohol content using Syke's hydrometer. Simultaneously, the temperature of the distillate was also measured. The alcohol content and the temperature were used to find the percentage of ethyl alcohol (EtOH) of the distillate, referring to the distillation chart. It was found that the percentage of ethyl alcohol was in the range of 6 % – 8 % depending upon the various ranges of different parameters.

**Reducing Sugar assay**

Ethanol fermentation is a biological process in which sugars are converted by microorganisms to produce ethanol and $CO_2$.The microorganism most commonly used in fermentation process is the yeasts and, among the yeasts, *Saccharomyces cerevisiae* is the preferred choice for ethanol fermentation [24].

Reducing sugars assay was carried out according to the Dinitrosalicylic method. Un-inoculated media was used as control for the assay. The optical densities of the samples were measured against the blank at 540nm.The glucose concentration was then calculated using standard glucose curve.

**Gas Chromatography (GC) Analysis**

Using this technique, the content of ethanol concentration can be measured in the different samples. The analysis performed by a gas chromatograph is called gas chromatography which analyzes the compound that can be vaporized without decomposition and GC may help in identifying a compound. In the study, GC technique has been adopted to analyze the concentration and the purity of ethanol in a given sample.

Generally chromatographic data is presented as a graph of detector response (y-axis) against retention time (x-axis), which is called a chromatogram. This provides a spectrum of peaks for a sample representing the analytes present in a sample eluting from the column at different times. Retention time can be used to identify analytes if the method conditions are constant. Also, the pattern of peaks will be constant for a sample under constant conditions and can identify complex mixtures of analytes. However, in most modern applications, the GC is connected to a mass spectrometer or similar detector that is capable of identifying the analytes represented by the peaks.

**Experimental setup for IC (Internal Combustion) Engine Test Rig**

The experimental test rig was developed keeping the necessary configurations of the IC Engine test rig using single cylinder, four stroke, air cooled and IC diesel engine which developed a maximum power output of 4.5 kW at constant speed of 1600 rpm (Table-12 & Fig-1).The schematic diagram of the experimental setup along with mechanism of action during fuel supply was also analyzed (Fig-2 & 3).The performance and emission parameters were carried-out with variable Bio-ethanol-Petroleum fuel blend ratios respectively based on the standard protocols.

**RESULTS AND DISCUSSION**

The fruit cultivars; Cashew apple and passion fruit were daily monitored (Fig- A & B). During the course of fermentation various parameters such as pH, specific gravity, alcohol concentration & titration was determined (Table-1, 2 & 3). The results show that, the fermentation is considerably fast in yeast compared to wheat fermentation mentioned in the earlier reports [25, 23, 19]. Result also shown that; the production of ethanol is also significantly more in case of fermentation using flocculating yeast. This is in accordance with the earlier reports made by Flávia Cristina dos Santos Lima *et al*., [26] and Evanie Devi Deenanath *et al*., [27].

**Juice Preparation for Passion fruit & Cashew Apple samples**

The juice yield was found to be significant in both Passion fruit & Cashew Apple samples. From, 20 kg of PFJ (yielded 9.85 L) and CAJ (yielded 5.6L) yielded considerable amount of juice during extraction process. Previous to fermentation both PFJ and CAJ were thawed, centrifuged andpretreated with gelatin powder to remove some secondary metabolites. The preparation of PFJ and CAJ was essential as the clear juice with a minimal to zero suspended solids which will allow the yeast to easily assimilate the sugars for growth and the production of ethanol (Table-4 & 5).

**Physico-Chemical Characterization**

The Juice extracted from *Passiflora edulis* and *Anacardium accidentale* all through the Fermentation process was subjected for physico-chemical characterization executed as per the standard protocols. The data has been represented in the tables respectively (Table-1 & 2).

**Evaluation of pH and Moisture**

Variation in pH was seen during execution of the experiment. pH was decreased at initial stage, then it attained a minimal stage & then it increased. The initial ph for passion fruit was 5.7 then it decreased to 4.9 and again it increased to 6.0. Passion fruit initial it was 5.5 then decreased to 5.0 & increased in the range of 5.2-6.0. For Cashew apple, initial it was 3.8then increased to 5.8 and the final range of pH was found to be 6.0. The Moisture content (%) of Passion fruit 13.45±0.04 and Cashew apple 9.25±0.01 was noticed after pre-treatment of the substrates are represented in the Table-3 [28-31, 9].

**Evaluation on reducing sugar**

The Reducing sugar in terms of percentage was analyzed and the result reveals; 0.74% in Passion fruit samples and 0.58% was noticed in Cashew apple fruit sample (Table-3).The yeast can grow both on simple sugars, such as glucose, and on the disaccharide sucrose. Furthermore, the availability of a robust genetic transformation system of *S. cerevisiae* along with a long history of this microorganism in industrial fermentation processes makes it most desired microorganisms for ethanol production [21, 17, 32]. *S. cerevisiae* has high resistance to ethanol, consumes significant amounts of substrate in adverse conditions, and shows high resistance to inhibitors present in the medium [33, 34, 27].

**Effect of specific gravity**

When the fermentation starts specific gravity decreases. Specific gravity of passion fruit reached 0.887at 52 hours, whereas, specific gravity of ginger and gooseberry reached 0.870 & 0.856 respectively (Table-4). After 14 days it reached a constant value indicating the end of fermentation [22, 20, 27].

**Assessment on Titration**

As the days increased fluctuating trend was seen in titration. The titratable acidity for passion fruit was 4.42g/L tartaric acid at the starting and reached 9.96 on last day. In case of Cashew apple it was 3.23 at the start and reached 8.89g/l tartaric acid on the last day [35, 12].

**Concentration of ethanol**

The ethanol content in the distillate was measured. The concentration of bio-ethanol in passion fruit sample was 11.4%, whereas the concentration of ethanol in cashew apple was 8.3% (Table-4 & 5). This value is higher than the report published by [18, 19, 35, 27].

**Gas Chromatography (GC) Analysis**

The function of the stationary phase in the column has separated ethanol, causing each one to exit the column at a different time (retention time). Other parameter that was used to alter the order or time of retention is the carrier gas flow rate, column length and the temperature.

The purity of the carrier gas is also frequently determined by the detector, though the level of sensitivity needed can also play a significant role. The spectrum of peaks for different samples representing the analytes present in the given samples eluting from the column at different times. 100% purity of bio-ethanol was noticed in Passion Fruit samples executed with increased days of fermentation using flocculating yeast cultures. The result of the given samples; sample 1- 8.7 ethanol, sample 2 - 15.8 ethanol, sample 3 - 11.6 ethanol (Table-6-10 & Graph-1-5). Among all the samples, sample 4 achieved 5.3% ethanol which gives 100% purity as compared to standard ethanol (Table-9 and Graph 4 & 6). Similar results were also obtained by [36-39, 12].

**Fig.A: Passion Fruit B: Cashew Apple**

**Table-1: Physico-chemical characterization of Juice extracted from *Passiflora edulis* all through the Fermentation process**

| Time (Days) | Yeast count *S. cerevisiae* (Log-CFU/ml) | Total soluble solids (°Brix) | pH | Alcohol (%-v/v) | Titratable Acidity as Citric Acid (%) | Fermentation Temp (°C) | Sugar Content (g/l) | Specific Gravity |
|---|---|---|---|---|---|---|---|---|
| 01 | 03 | 14 | 3.1 | 0.0 | 0.68 | 20 | 92 | 1.064 |
| 02 | 04 | 11 | 3.2 | 3.6 | 0.72 | 20 | 85 | 1.052 |
| 03 | 05 | 08 | 3.4 | 4.8 | 0.79 | 22 | 79 | 1.048 |
| 04 | 06 | 06 | 3.5 | 5.4 | 0.86 | 24 | 71 | 1.042 |
| 05 | 07 | 05 | 3.8 | 6.5 | 0.89 | 25 | 68 | 1.037 |
| 06 | 09 | 04 | 3.9 | 8.7 | 0.92 | 26 | 59 | 1.033 |
| 07 | 10 | 02 | 4.2 | 9.5 | 0.95 | 28 | 52 | 1.028 |
| 08 | 12 | 1.5 | 4.5 | 10.7 | 0.98 | 30 | 48 | 1.024 |
| 09 | 13 | 1.4 | 5.2 | 12.4 | 1.15 | 32 | 41 | 1.018 |
| 10 | 14 | 0.8 | 5.8 | 12.9 | 1.21 | 34 | 38 | 1.014 |
| 11 | 15 | 0.5 | 6.0 | 13.5 | 1.28 | 35 | 34 | 1.008 |
| 12 | 18 | 0.3 | 6.5 | 15.8 | 1.45 | 36 | 31 | 1.006 |
| 13 | 20 | 0.2 | 6.6 | 18.6 | 1.56 | 38 | 28 | 1.005 |
| 14 | 24 | 0.07 | 6.8 | 19.5 | 1.66 | 40 | 19 | 1.002 |

**Table-2: Physico-chemical characterization of Juice extracted from *Anacardium accidentale* all through the Fermentation process**

| Time (Days) | Yeast count *S. cerevisiae* (Log-CFU/ml) | Total soluble solids (°Brix) | pH | Alcohol (%-v/v) | Titratable Acidity as Citric Acid (%) | Fermentation Temp (°C) | Sugar Content (g/l) | Specific Gravity |
|---|---|---|---|---|---|---|---|---|
| 01 | 03 | 20 | 3.1 | 0.0 | 0.72 | 20 | 88 | 0.996 |
| 02 | 04 | 19 | 3.2 | 3.2 | 0.74 | 20 | 80 | 0.952 |
| 03 | 05 | 18 | 3.4 | 4.5 | 0.78 | 22 | 75 | 0.946 |
| 04 | 06 | 16 | 3.5 | 5.6 | 0.80 | 24 | 68 | 0.938 |
| 05 | 07 | 13 | 3.8 | 6.7 | 0.82 | 25 | 62 | 0.922 |
| 06 | 09 | 11 | 3.9 | 8.4 | 0.86 | 26 | 56 | 0.908 |
| 07 | 10 | 08 | 4.2 | 9.6 | 0.92 | 28 | 50 | 0.894 |
| 08 | 12 | 6.5 | 4.5 | 10.4 | 0.96 | 30 | 46 | 0.882 |
| 09 | 13 | 4.4 | 5.2 | 11.6 | 1.00 | 32 | 44 | 0.865 |
| 10 | 14 | 3.2 | 5.8 | 11.9 | 1.14 | 34 | 42 | 0.860 |
| 11 | 15 | 2.5 | 6.0 | 12.2 | 1.24 | 35 | 38 | 0.846 |
| 12 | 18 | 2.1 | 6.5 | 12.5 | 1.42 | 36 | 36 | 0.828 |
| 13 | 20 | 1.8 | 6.6 | 12.8 | 1.49 | 38 | 35 | 0.798 |
| 14 | 24 | 1.6 | 6.8 | 13.6 | 1.54 | 40 | 34 | 0.786 |

**Table-3: Showing Physico-chemical characteristic features in Passion fruit and Cashew apple after pre-treatment**

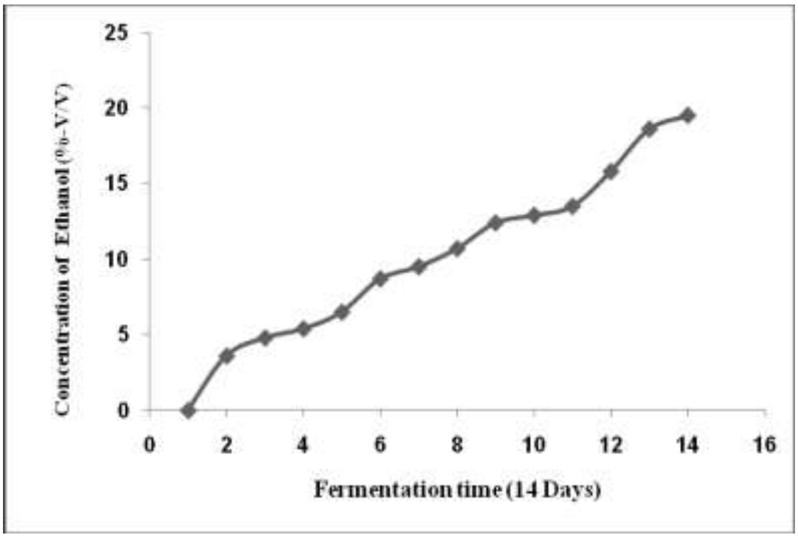
| SL. No. | Parameters analyzed | Passion fruit Juice(PFJ) | Cashew Apple Juice ICAJ) |
|---|---|---|---|
| **1.** | pH | 5.2—6.0 | 5.8-6.0 |
| **2.** | Moisture (%) | 13.45±0.04 | 9.25±0.01 |
| **3.** | Soluble Solids(⁰Brix) | 0.00±0.00 | 0.004±0.00 |
| **4.** | Reducing Sugar (%) | 0.74±0.02 | 0.58±0.08 |

**Table-4: Showing different parameters and respective yields of Ethanol for Passion Fruit samples**

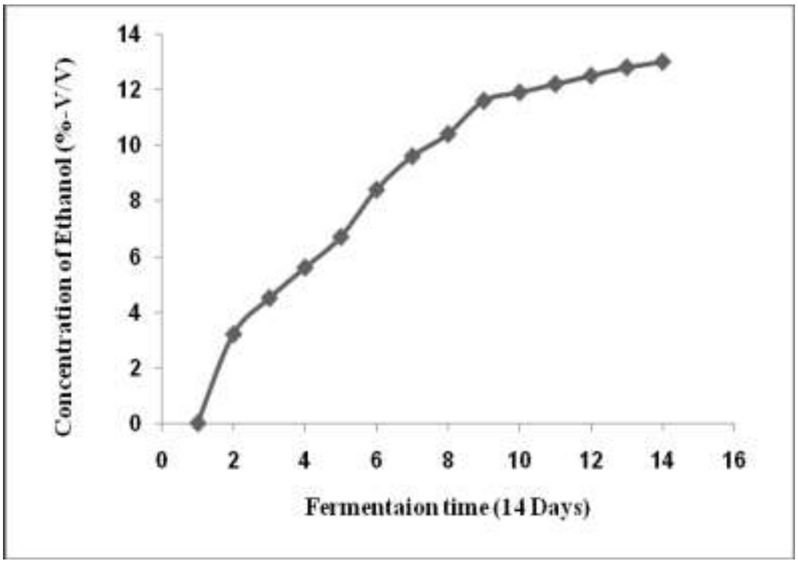
| SL. No. | Wine(Yeast) | pH | Specific Gravity | Ethanol Conc.% |
|---|---|---|---|---|
| 01 | Passion fruit | 6.0 | 0.998 | 15.2 |
| **02** | Passion fruit | 5.2 | 0.890 | 11.4 |
| **03** | Passion Fruit | 5.9 | 0.833 | 8.2 |

**Table-5: Showing different parameters and respective yields of Ethanol for Cashew Apple Fruit samples**

| SL. No. | Wine(Yeast) | pH | Specific Gravity | EthanolConc. % |
|---|---|---|---|---|
| 01 | Cashew Apple | 6.0 | 0.887 | 8.3 |
| 02 | Cashew Apple | 5.8 | 0.850 | 7.0 |
| 03 | Cashew Apple | 5.8 | 0.733 | 6.5 |



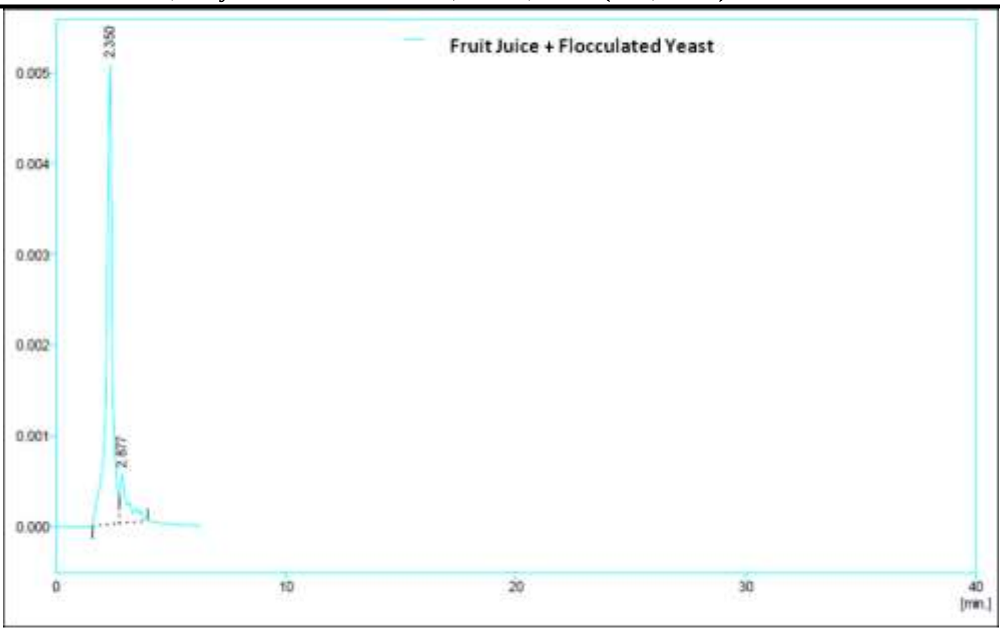

**Graph-1: Showing Ethanol concentration (%) v/s Days of Fermentation in Passion fruit sample**




**Graph-2: Showing Ethanol concentration (%) v/s Days of Fermentation in Cashew apple fruit sample**

**Table-6: Showing GC Analysis of Juice sample of *P. edulis* after fermentation using flocculated Yeast**

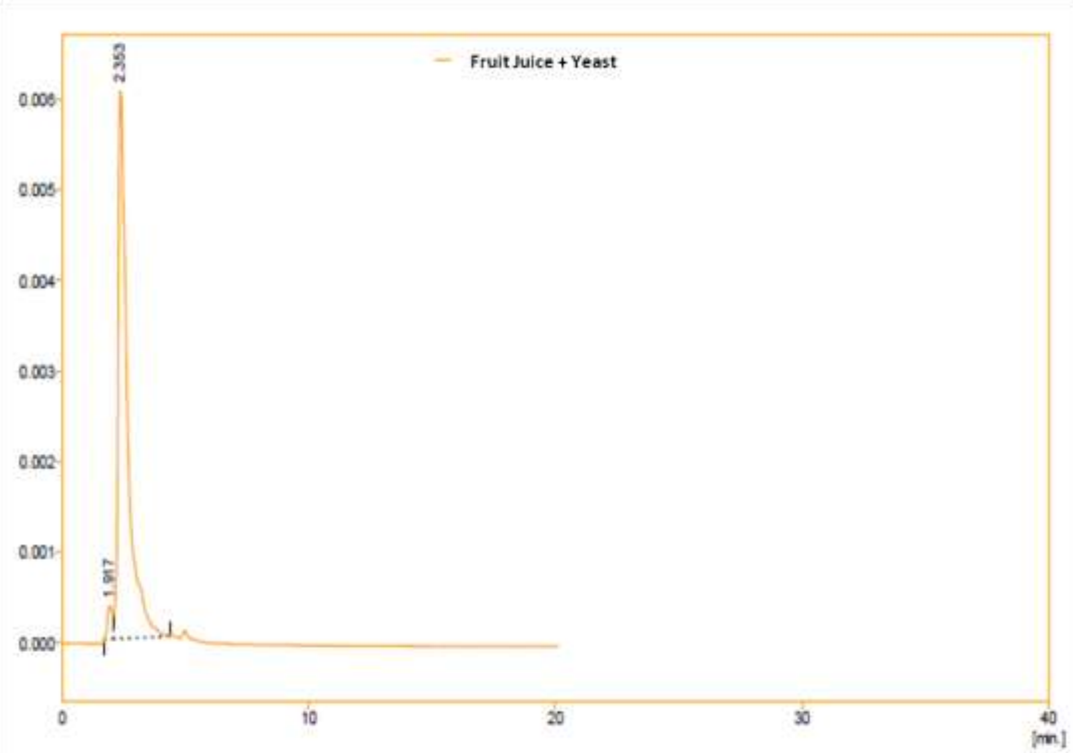
| SL.No. | Retention Time (Time) | Area(mV.s) | Area(%) |
|---|---|---|---|
| 1. | 2.350 | 87.450 | 86.80 |
| 2. | 2.877 | 13.345 | 13.20 |
| Total | | 100.79 | 100.0 |




**Graph-3: GCA analysis of fruit juice sample of *Passiflora edulis* after fermentation using flocculated Yeast**

**Table-7: Showing GC Analysis of fruit juice sample of *A. accidentale* after fermentation using Yeast**

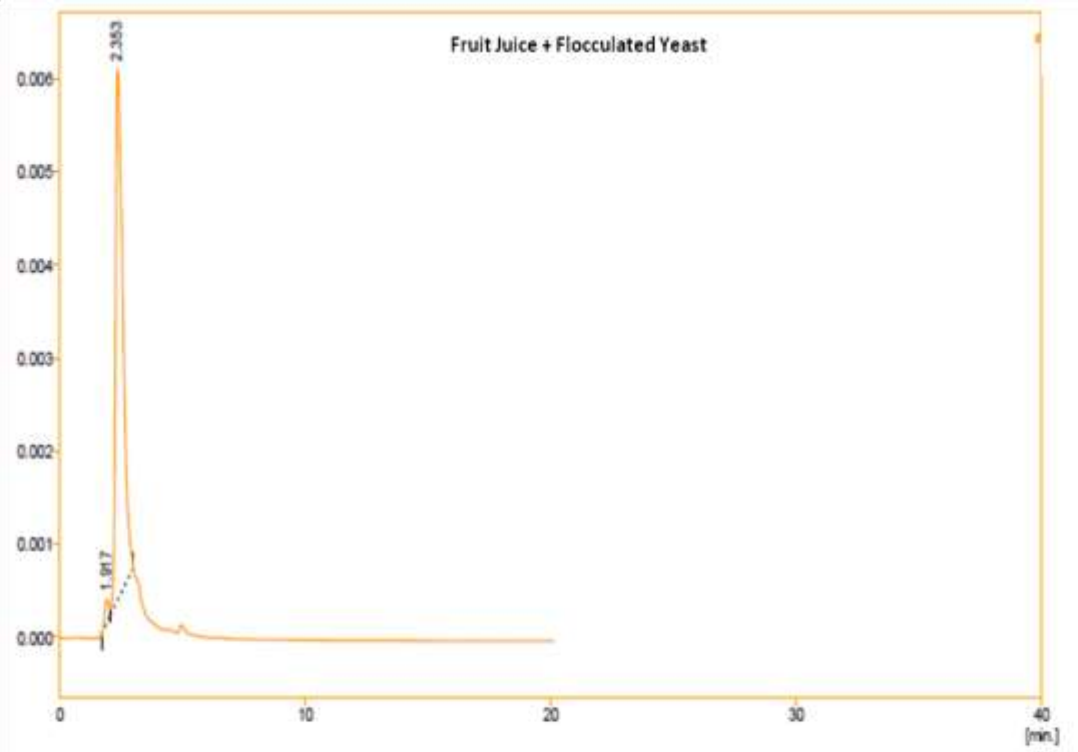
| SL. No. | Retention Time (Time) | Area (mV.s) | Area(%) |
|---|---|---|---|
| 1. | 1.917 | 5.124 | 3.1 |
| 2. | 2.353 | 158.534 | 96.9 |
| Total | | 163.658 | 100.0 |




**Graph-4: GC Aanalysis of fruit juice sample of *A. accidentale* after fermentation using Yeast**

**Table-8: Showing GC Aanalysis of fruit juice sample of *P. edulis* after fermentation using flocculated Yeast**

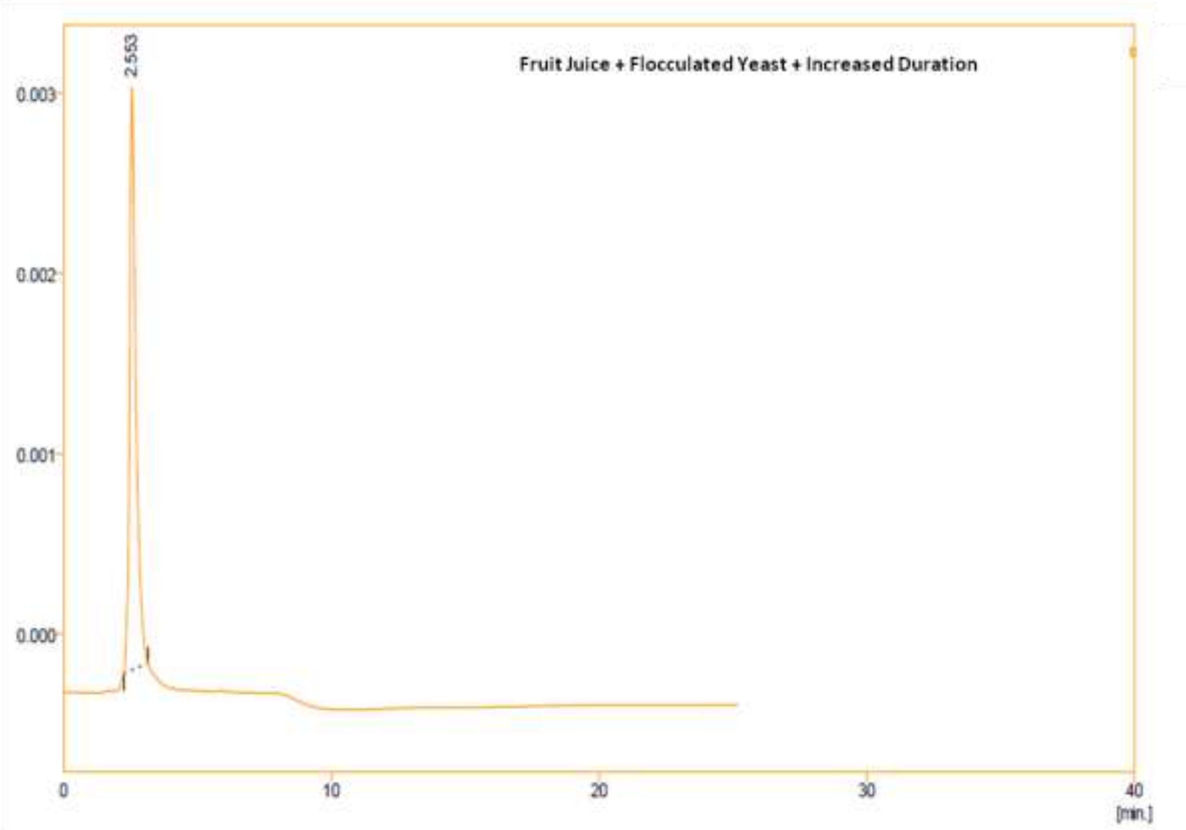
| SL. No. | Retention Time (Time) | Area (mV.s) | Area (%) |
|---|---|---|---|
| 1. | 1.917 | 2.890 | 2.4 |
| 2. | 2.353 | 116.721 | 97.6 |
| Total | | 119.611 | 100.0 |




**Graph-5: GC analysis of fruit juice sample of *P. edulis* after fermentation using flocculated Yeast**

**Table-9: Showing GC Aanalysis of fruit juice sample of *A. accidentale* after fermentation using flocculated Yeast with increased duration**

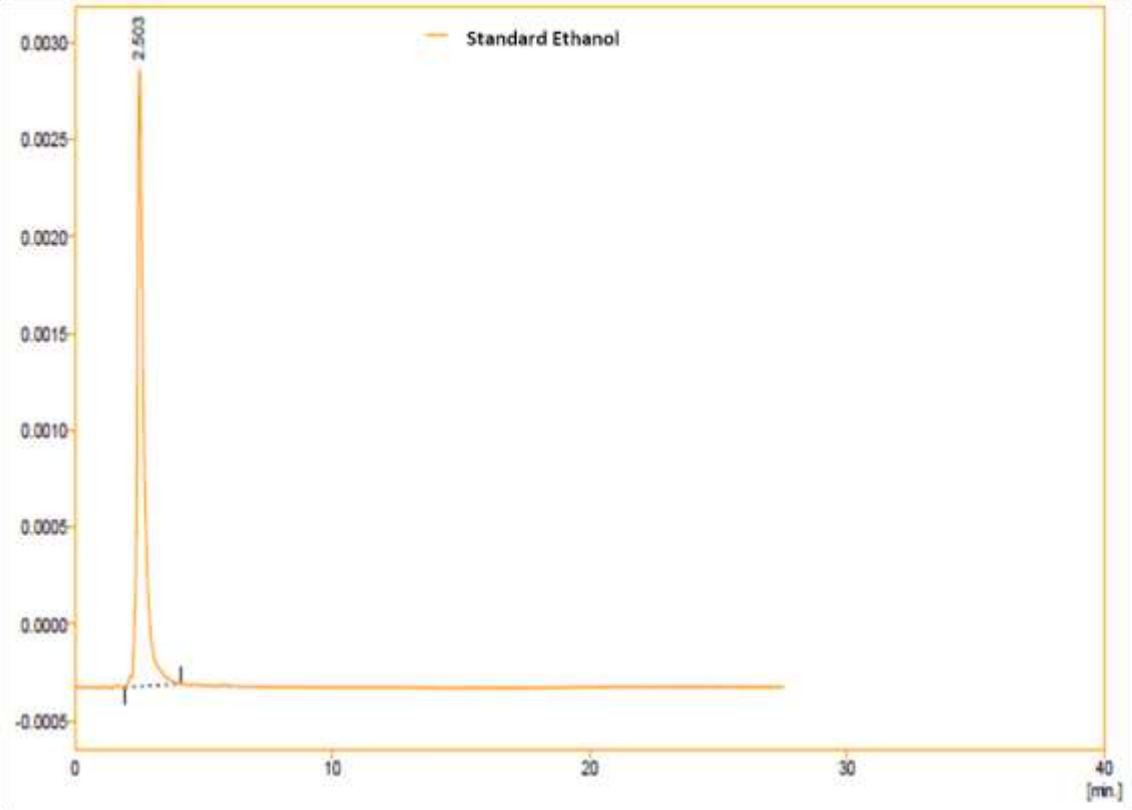
| SL. No. | Retention Time (Time) | Area (mV.s) | Area (%) |
|---|---|---|---|
| 1. | 2.553 | 53.367 | 100.0 |
| Total | | 119.611 | 100.0 |



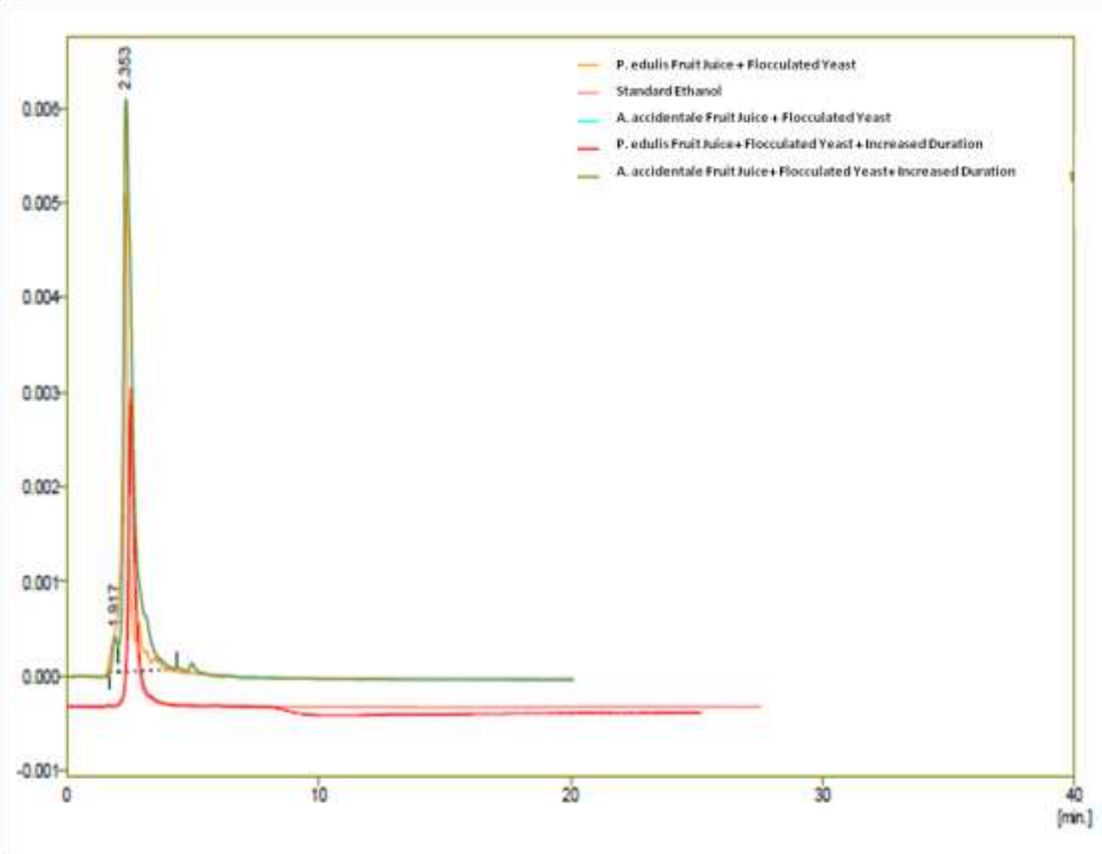

**Graph-6: GC analysis of fruit juice sample of *A. accidentale* after fermentation using flocculated Yeast with increased duration**

**Table-10: Showing GC-MS analysis of Standard Ethanol**

| SL. No. | Retention Time (Time) | Area (mV.s) | Area (%) |
|---|---|---|---|
| 1. | 2.503 | 58.483 | 100.0 |
| Total | | 58.483 | 100.0 |




**Graph-7: GC Showing of Standard Ethanol**




**Graph-8: Showing GC Aanalysis of *Passiflora edulis* and *Anacardium accidentale* fruit samples comparing with Standard.**

**Characteristic features of Bio-ethanol**

The obtained Bio-ethanol from non-edible fruit samples was subjected for analysis with respect to various properties as per the ASTM standards. In the evaluation, Ethanol was found to be with high octane number, low flame temperature, high density, and high latent heat of vaporization. Ethanol provides reduction in emission and increases the performance of SI engine, like specific fuel consumption, brake power, torque, volumetric and brake thermal efficiency (Table-11).

**Table -11: Characteristic features of Bio-Ethanol, Petrol, and Diesel.**

| SL. No. | Properties | Unit | Bio-ethanol | Diesel oil |
|---|---|---|---|---|
| | Chemical Formula | --- | $CH_3CH_2OH$ | $C_{12}H_{23}$ |
| 1. | Density at $15^{O}C$ | $Kg.m^{-3}$ | 826 | 865 |
| 2. | Lower Calorific Value | $MJ.kg^{-1}$ | 32.8 | 45.6 |
| 3. | Octane Number VM | -- | 125 | -- |
| 4. | Cetane Number | -- | 9 | 56 |
| 5. | Specific gravity | @ $15^{o}C$ | 0.826 | 0.814 |
| 6. | Kinamatic Viscosity | @ $40^{O}C$ (cSt) | 2.45 | 2.21 |
| 7. | Boiling Point | ($^{O}C$) | 185-355 | -- |
| 8. | Flash Point | ($^{O}C$) | 36 | 30 |
| 9. | Calorific value | KJ/Kg | 28440 | 46820 |
| 10. | Auto Ignition Temp. | $^{o}C$ | 372 | 240 |

**Engine Efficiency Parameters**

In the study, an internal combustion engine (ICE) is used to analyze the performance of and efficiency of Bio-ethanol derived from fruit bio-resources. The IC engine is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is applied typically to pistons, turbine blades, rotor or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy (Table-12 and Fig-2 & 3).

In the IC Engine system, the *top dead center* (TDC) of a piston is the position where it is nearest to the valves; *bottom dead center* (BDC) is the opposite position where it is furthest from them. A *stroke* is the movement of a piston from TDC to BDC or vice versa, together with the associated process. While an engine is in operation, the crankshaft rotates continuously at a nearly constant speed. In a 4-stroke ICE, each piston experiences 2 strokes per crankshaft revolution in the following approach.

**Intake**, **induction** or **suction**

The intake valves are open as a result of the cam lobe pressing down on the valve stem. The piston moves downward increasing the volume of the combustion chamber and allowing air to enter in the case of a CI engine or an air fuel mix in the case of SI engines that do not use direct injection. The air or air-fuel mixture is called the *charge* in any case.

**Compression**

In this stroke, both valves are closed and the piston moves upward reducing the combustion chamber volume which reaches its minimum when the piston is at TDC. The piston performs work on the charge as it is being compressed; as a result its pressure, temperature and density increase; an approximation to this behavior is provided by the ideal gas law. Just before the piston reaches TDC, ignition begins. In the case of a SI engine, the spark plug receives a high voltage pulse that generates the spark which gives it its name and ignites the charge. In the case of a CI engine the fuel injector quickly injects fuel into the combustion chamber as a spray; the fuel ignites due to the high temperature.

**Power** or **working stroke**

The pressure of the combustion gases pushes the piston downward, generating more work than it required to compress the charge. Complementary to the compression stroke, the combustion gases expand and as a result their temperature, pressure and density decreases. When the piston is near to BDC the exhaust valve opens. The combustion gases expand irreversibly due to the leftover pressure—in excess of back pressure, the gauge pressure on the exhaust port—; this is called the *blow down*.

**Exhaust**

The exhaust valve remains open while the piston moves upward expelling the combustion gases. For naturally aspirated engines a small part of the combustion gases may remain in the cylinder during normal operation because the piston does not close the combustion chamber completely; these gases dissolve in the next charge. At the end of this stroke, the exhaust valve closes, the intake valve opens, and the sequence repeats in the next cycle. The intake valve may open before the exhaust valve closes to allow better scavenging (Fig-3).

**Table-12: Technical specifications of CI Engine**

| Sl. No. | Components | Specification |
|---|---|---|
| 1. | No. of cylinder | 1 |
| 2. | Type of injection | Direct |
| 3. | Rated power at 1500 rpm (kW) | 4.41 |
| 4. | Bore (mm) | 87.5 |
| 5. | Stroke (mm) | 110 |
| 6. | Compression ratio | 17.5 |
| 7. | Method of cooling | Air cooled with radial fan |
| 8. | Displacement volume, liters | 0.662 |
| 9. | Fuel injection timing BTDC | $23^{o}C$ |
| 10. | Number of injector nozzle holes | 3 |

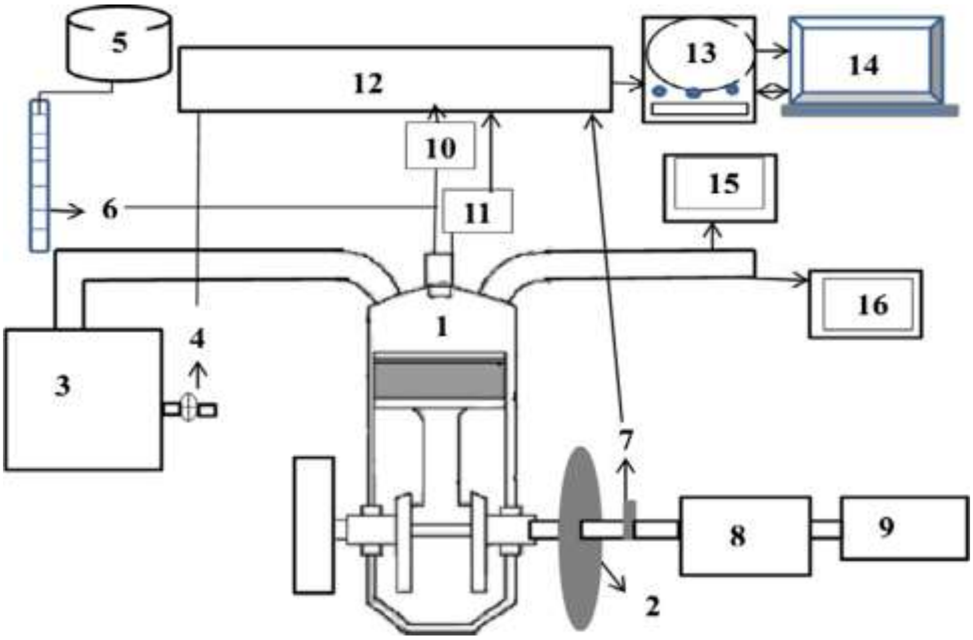
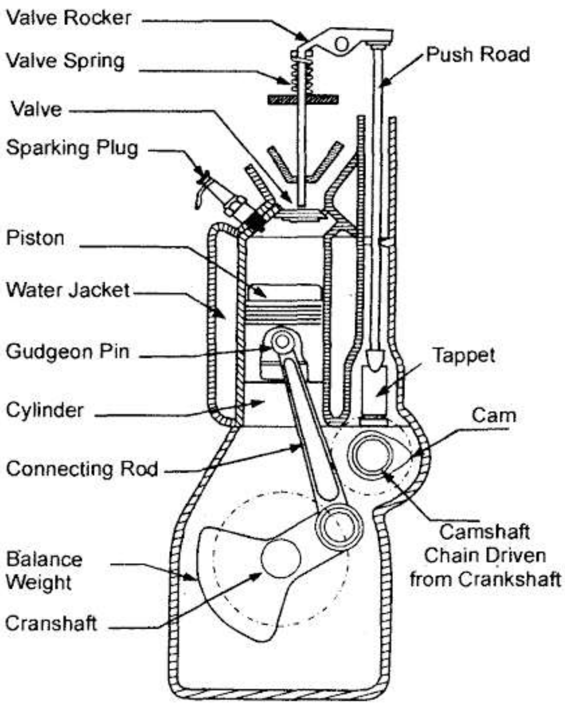



**Fig-1: Schematic diagram of experimental setup**

1. Engine; Flywheel; 3. Air box; 4. Manometer; 5. Fuel tank; 6. Burette; 7. Speed sensor; 8. Alternator; 9. Loads cell; 10. Fuel injector; 11. Pressure transducer; 12. Control panel board; 13. Data acquisition card; 14. Computer; 15. AVL 437C Smoke meter; 16.AVL Digas 444 analyser




Internal combustion engine mechanism.

The internal Combustion Engine system with standard specification was employed to evaluate performance of the Engine with variable blends of Bio-ethanol and Petroleum Diesel (Table-12). In addition, the mechanism of action with the CI engine during the supply of fuel was enunciated (Fig.1&2). The Effect of ethanol–gasoline blends on CO and HC emissions in last generation four stork CI engines within the cold-start transient was evaluated, which works with ethanol-gasoline mixture by10%, 20%, and 30% by volume called G10, G20, and G30. This study showing that, the reduction of the CO and HC emission at cold-start transient commercial gasoline, with the 20% v/v ethanol blend achieving the highest emission decrease (Table-13).

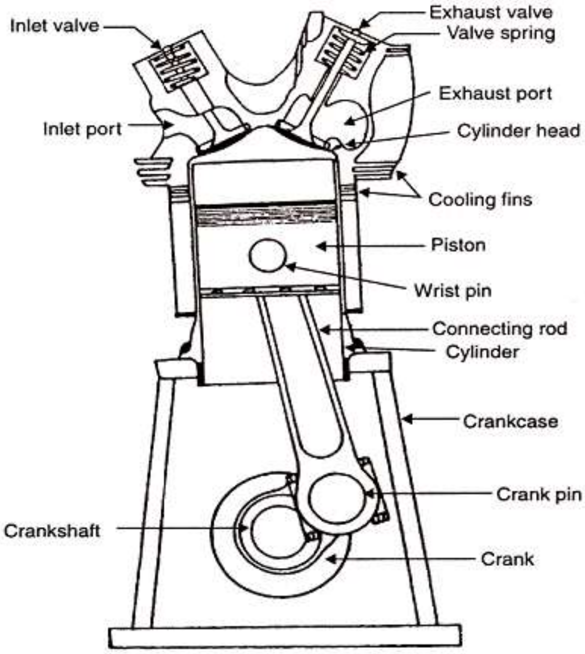



**Fig-2: Showing mechanism of Internal Combustion Engine**

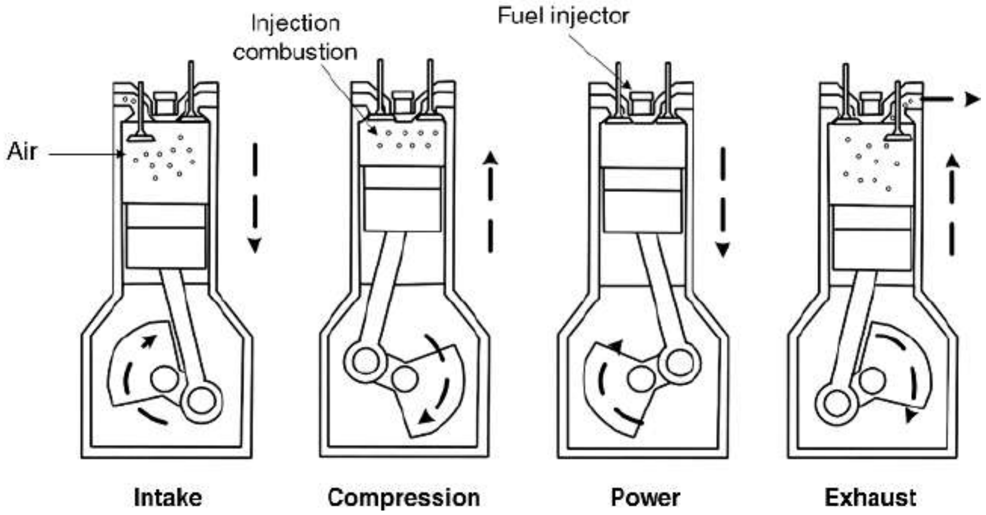



**Fig-3: Showing mechanism of action Internal Combustion Engine during fuel supply**

The burning of fossil fuel and emission of hazardous gases are measured as a major cause of global warming and environmental pollutions [40]. The ethanol produced from fruit resources was tested by using the CI Engine of above specification. In the evaluation, the hydrocarbon content for fuel consumption (ml/sec) was measured at 100% gasoline, B5 (A blend of 5% bio-ethanol/95% gasoline) and B10 (A blend of 10% bio-ethanol/90% gasoline). In the Table 4, the hydrocarbon content in B5 and B10 were found to considerably significant as compared to Gasoline alone with hydrocarbon. This showed that, the fuel blend was burned more completely in BFDE5 and BFDE10 as compared to the 100% gasoline permitting emission with fewer unburned hydrocarbons (HC). The performance of the engine and emission of gases were strongly supporting the quality of the Bio-ethanol produced by the fermentation of fruits.

**Engine performance analysis**

**Brake Specific Energy Consumption (BSEC)**

The variation in the brake specific energy consumption of diesel and bio-ethanol–diesel emulsions at different loads. The fuel consumption characteristics of an engine are generally expressed in terms of the specific energy consumption in MJ/kW h. If two different fuels of different density and calorific values are blended, then the brake specific energy consumption is considered, instead of the BSFC. It can be observed from the figure that the BSEC decreases with an increasein the brake power. It can also be noticed from the fig. xxx that the BSEC for the BFDE5, BFDE10, and BFDE15 emulsions is found to be higher by about 17.26%, 17.5%, and 30.12%, respectively, than that of diesel at full load. This may be due to the lowering of the energy content of the emulsions caused by the presence of water.

**Thermal energy balance**

The useful work increases as the load increased, but other losses are decreased. The useful work for the BFDE5, BFDE10, and BFDE15 emulsions is found to be higher by about 3%, 4%, and 6%, respectively. At full load, the heat loss through the exhaust is found to be higher for all the emulsions compared to that of diesel. Though there is an efficient work is achieved by the emulsions, some amount of heat is lost, may be due to the burning of fuels at the end of expansion stroke. Other losses are minimized with higher percentage of bio-ethanol operation (Table-14).

**Engine Emission analysis**

**Brake Specific Hydrocarbon (BSHC) emission**

The variation in the BSHC emissions with respect to different percentages of bio-ethanol in bio-ethanol–diesel emulsions at different loads. It can be observed that the BSHC emissions of the three emulsions are found to be higher than that of diesel at full load. The BSHC emissions of BFDE10 and BFDE15 are found to be higher by about 8.33% and 22.16%, comparedto that of diesel at full load. This may be due to the fact that the increase in the volume of bio-ethanol increases the heat of evaporation and formation of a quench layer. This might slow down the vaporization and mixing of fuel with air, and hence, the BSHC emissions for a given power output increased with an increase in the percentage of bio-ethanol in the emulsions. The BSHC values of diesel, BFDE5, BFDE10, and BFDE15 at full load are recorded as 0.025, 0.0279, 0.0323, and 0.0368 g/kWh, respectively, at full load (Table-13 & 15).

**Table-13: Details of devices used in the analysis of Bio-fuel with CI Engine**

| SL. No. | Device used in the study | Reference Range | precision | Improbability (%) |
|---|---|---|---|---|
| 1. | Load Indicator (W) | 250-6000 | ±10 | 0.25 |
| 2. | Temperature Indicator ($^oC$) | 0-900 | ±1 | 0.16 |
| 3. | Speed sensor (rpm) | 0-10,000 | ±10 | 1.2 |
| 4. | Burette (cc) | 1-30 | ±0.2 | 1.8 |
| **Exhaust Gas analyzer** | | | | |
| 1. | NO (ppm) | 0-5000 | ±50 | 0.8 |
| 2. | HC (ppm) | 0-20,000 | ±10 | 0.75 |
| 3. | CO (%Vol) | 0-10 | ±0.03 | 1.2 |
| 4. | Smoke Meter (%) | 0-100 | ±1 | 1.6 |
| 5. | Pressure Transducer (bar) | 0-110 | ±1 | 0.25 |
| 6. | Crank angle encoder ($^oCA$) | | ±1 | 0.6 |

**Table-14: Showing thermal energy balance at full load for Bio-ethanol and Diesel emulsions**

| SL. No. | Parameters (%) | BFDE5 | BFDE10 | BFDE15 | DIESEL |
|---|---|---|---|---|---|
| 1. | Useful Work | 35.841 | 37.656 | 39.224 | 32.226 |
| 2. | Heat to Exhaust | 18.240 | 183941 | 19.565 | 17.880 |
| 3. | Heat carried by Lubricating Oil | 17.660 | 17.202 | 17.409 | 16.676 |
| 4. | Un accounted losses | 29.556 | 29.885 | 30.014 | 33.845 |

**Table-15: Emission Parameters in IC Engine system**

| SL. No. | Type of Fuel | Oxygen content (wt.%) | CO Cold extra emissions (g) | HC Cold extra emissions (g) |
|---|---|---|---|---|
| 1. | BFDE5 | 5 | 12.50 | 2.25 |
| 2. | BFDE10 | 10 | 10.25 | 1.45 |
| 3. | BFDE15 | 15 | 8.5 | 1.30 |

It was carried out to investigate the combustion, performance and emission characteristics of bio-ethanol with diesel fuel on a single-cylinder, four stroke, direct injection and water cooled diesel engine. This study gives the comparative measures of brake specific fuel consumption, brake power, brake thermal efficiency, mechanical efficiency, volumetric efficiency, CO, $CO_2$, HC, NOx and smoke opacity. The Bio-ethanol was blended at 5%, 10%, 15% and 20% ratio with diesel fuel in the present study. The results indicate that the CO and HC emissions were lower than diesel at 15% of MSO, and NOx emissions decreased up to 20.5% for 15% MSO when compared with diesel. From the investigation it can be concluded that bio-ethanol can be used as an alternative to diesel in a compression ignition engine without any engine modifications (Table-13).

**Summary and Conclusion**

The world's present economy is highly dependent on various fossil energy sources such as oil, coal, natural gas, etc. These are being used for the production of fuel, electricity and other goods. Excessive consumption of fossil fuels, particularly in large urban areas, has resulted in generation of high levels of pollution during the last few decades. The level of greenhouse gasses in the earth's atmosphere has drastically increased. With the expansion of human population and increase of industrial prosperity, global energy consumption also has increased gradually.

Import of transport fuel is affected by limited reserves of fossil fuel. Annual global oil production will begin to decline within the near future. In this scenario, renewable sources might serve as an alternative.

Wind, water, sun, biomass, geothermal heat can be the renewable sources for the energy industry whereas fuel production and the chemical industry may depend on biomass as an alternative source in the near future. All petroleum-based fuels can be replaced by renewable biomass fuels such as bio-ethanol, bio-diesel, bio-hydrogen, etc., derived from Cereals, millets, sugarcane, Fruit cultivars, algae, etc.

In the present study, the existing technologies were adopted for bio-ethanol production from fruit cultivars; Passion fruit and Cashew apple fruit samples. The bio-ethanol content of both Passion fruit and Cashew apple fruit juice samples by employing fermentation with increased duration using flocculating Yeast has been achieved. The result concludes that, the bio-ethanol content of Passion fruit by yeast fermentation is significantly very high compared to Cashew apple fruit sample. Furthermore, other than the yeast fermentation, in the ethanol production, using flocculating Yeast culture can facilitates high amount of bio-ethanol recovery in the fruit samples with 100% purity. Besides, the results also show that, the bio-ethanol obtained in Passion fruit is of highest purity and can be recommended to use as fuel ethanol.

In the study, gasoline is taken as reference which is blended with ethanol. Physical properties relevant to the fuel were determined for the four blends of gasoline and ethanol. A four cylinder, four stroke, varying rpm, Petrol engine connected to eddy current type dynamometer was run on blends containing 5%,10%,15%,20% ethanol and performance characteristics were evaluated. We can conclude from the result that using 10% ethanol blend is most effective, we can utilize it, and further use in SI engines with little constraint on material used to sustain little increase in pressure.Further, the spark ignition engine with ethanol and check the performance and emission analysis and the reduction on the emission of CO, $NO_X$, $CO_2$ was recorded. Hence blending of ethanol at about 10-20 % can lead to a better performance of engine compare with pure diesel.

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