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# Bioethanol production from the fermentation process using vegetable wastes as feedstock materials to produce ethanol-gasoline blends as improved fuel

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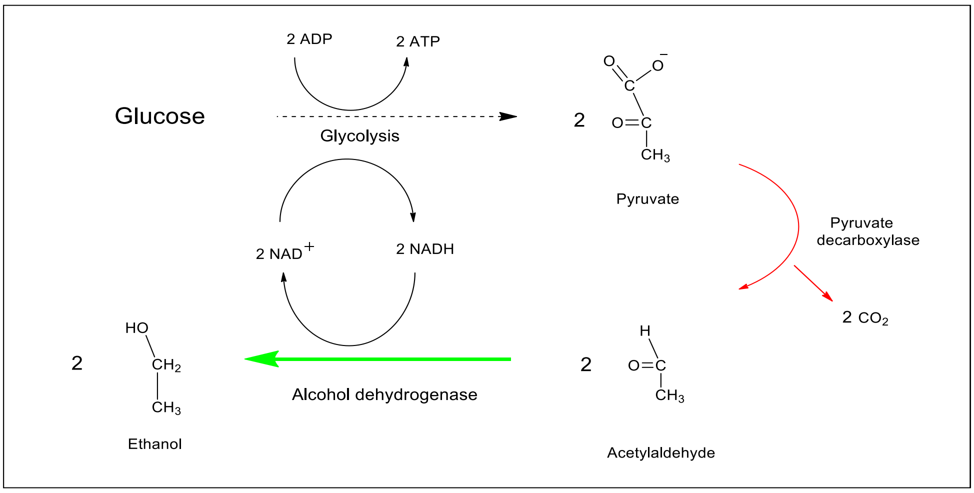
**Abstract**

The present work is to investigate the potential bioethanol production from local vegetable wastes as a possible feedstock via the fermentation process. The waste materials were subjected to a pretreatment process before the fermentation process. Conversion of biomass was performed using cost-effective dry yeast such as Saccharomyces cerevisiae for 5 to 7 days. This research aims to determine bioethanol percentage from vegetable wastes. Besides, the fermented solutions were evaluated and analyzed using variations parameters including sugar content, pH value, and yield during yeast fermentation at 32°C for the production of alcohol. It was noted that the sugar content of the feedstocks used was reduced during the fermentation process, whereas the pH values decreased slightly. The decaying vegetables, including beetroot, carrot, and potatoes, recorded a maximum percentage bioethanol yield of 7%, 5%, and 4.3% respectively. Our work exhibits a promising approach for bioethanol production on a large scale from inexpensive organic wastes and yeast. Furthermore, the bioethanol obtained was blended with pure gasoline to produce ethanol-gasoline blended fuel in various proportions of 0%, 3%, 5%, 7%, 9%, 11%, 13%, and 15%. The resulting alternative fuel characteristics were assessed experimentally using (ASTM) standard methods. The bioethanol-gasoline blend properties including Reid vapor pressure (RVP), density, and Research Octane Number (RON) were measured according to ASTM standard methods. Single-cylinder of spark ignition engine was used to study the impact of ethanol/gasoline blends on engine performance. Overall, the results showed that the RON of gasoline was enhanced remarkably with the increase in ethanol ratio.

## Introduction:

As the depletion of the world's fossil fuel is carried out, the cost of fuel continues rising besides the environmental and economic concerns that created a strong market for biofuels [1-4]. So, thus an alternative energy source is needed urgently by the world as a result of the rapid exhaustion of the world's energy supply [5, 6]. It can be seen that the world is becoming too dependent on limited sources of fuel-based fossil resources that later cannot bear the burden to meet future energy demands [7]. The overuse of fossil fuels is leading to their depletion, which created vast environmental problems such as the global warming phenomena that are being escalated by the burning of petroleum-based fossil fuels [8, 9]. Global environmental concerns and the consequent need to minimize greenhouse gas emissions have encouraged to switch to the use of biofuel as an alternative fuel from renewable resources [10]. Biofuels are emerging worldwide as a potential renewable energy source instead of fossil fuels, especially given their much lower greenhouse gas emissions and their industrial and economic value [11-13]. In this regard, the production of biofuels based on biomass resources is currently a priority in the fuel industry of many developed countries [14]. At present, the production of bioethanol from lignocellulosic materials, and organic wastes has long been considered an alternative solution to environmental and energy demand concerns that are being faced all over the world [15]. Vegetable and fruit wastes are commonly disposed of, and their loss leads to nutritional, economic, and environmental issues. A huge amount of vegetable and fruit residues originate from unconsumed parts of fruits and vegetables at different stages of the food supply chain [16, 17]. These organic wastes can be subjected to biological and chemical reactions to produce bioethanol; overripe vegetables have chemical potentials due to highly complex saccharides in the form of lignocellulose. So vegetable wastes could be digested into D-glucose and D-xylose, which could further convert to bioethanol by microorganisms via a fermentation process [18]. Regarding the mechanism of alcoholic fermentation, glucose molecules are converted to ethanol ($C_2H_5OH$) and carbon dioxide ($CO_2$) under anaerobic conditions as shown in scheme 1. Ethanol fermentation is also known as alcoholic fermentation which converts sugars such as glucose, fructose, and sucrose into energy (ATP), ethanol, and carbon dioxide as by-products. One glucose molecule can be converted into two ethanol molecules and two carbon dioxide molecules through the fermentation process [19].




**Scheme 1**: Alcoholic fermentation mechanism of glucose.

Vegetable wastes have been considered to be a useful source of biomass for bioethanol production. Alcoholic fermentation converts saccharide and starchy sources into ethanol and carbon dioxide with released energy. [17]. Ethyl alcohol (ethanol) has unique properties such as volatile, flammable, colorless, and oxygen-containing organic chemical compound, which is commonly employed as additives to fuel. Bioethanol is considered a clean burning renewable fuel with its economic and environmental benefits, it can be mixed with gasoline at various percentages thus it is being used as octane booster fuel as a result of its high oxygen content, which reduces net carbon dioxide emissions and more complete combustion of fuel [20]. Bioethanol-gasoline blend has a great advantage as it reduces greenhouse gases remarkably relative to pure regular gasoline and generates alternative friendly fuel [4, 21, 22]. Previous studies have been conducted on ethanol-gasoline blended fuels to find out the appropriate amount of ethanol. Various ethanol-gasoline blends have been investigated to determine and characterize the optimum amount of ethanol that should be used in biofuel as alternative fuel without engine modifications. A research group [23] studied the effects of ethanol addition to pure gasoline on an SI engine performance. Four gasoline blends containing 10, 20, 30, and 40 vol. % ethanol have been tested respectively. It was found that the increase of ethanol content increases the RON but decreases the heating value. The 10 vol. % addition of ethanol had the most obvious effect on increasing the RON value. Under various compression ratios of an engine, the optimum blend rate was found to be 10 vol. % ethanol with 90 vol. % pure gasoline. EL-Bassiouny et al. [24] revealed that the optimum selected percentages of ethanol with gasoline were 2.5 and 5% vol.%. Experimental results have shown that among the various blends, the blend of 2.5 and 5 vol. % ethanol was the most suitable one from the engine performance and CO emissions. Sugiarto and his group [25] investigated the impact of ethanol addition to low Octane Number gasoline, in terms of RON value, gasoline (Octane Number 87) was blended with four different percentages of ethanol, namely 5, 10, 15, and 20 vol. %. It was found that the RON of gasoline increased continuously with the ethanol percentages in gasoline. Notably, a significant increase occurred when using pure gasoline was blended with 20 vol.% of bioethanol, The RON value jumped to 11 points compared to pure gasoline.

The purpose of this study is to convert the vegetable wastes as inexpensive sources to valuable bioethanol via a fermentation process; bioethanol was then purified using the distillation units to obtain high-purity ethanol for fuel purposes. The commercial pure gasoline (RON 82.5) was blended with four different percentages of bioethanol to enhance the quality of standard gasoline for a spark-ignition engine without any modifications. Bio ethanol-gasoline blended fuels were analyzed and tested by various techniques such as density, Reid Vapor Pressure (RVP), RON, and ASTM distillation, and compared with those of pure gasoline fuel. Finally, the optimum gasoline blend sample is determined for SI engine.

**Experimental procedure.**

All the reagents and chemicals were purchased from Scientific Global Lab Suppliers such as 3, 5-dinitro salicylic acid –DNSA (Sigma-Aldrich – purity 98 %), Potassium sodium tartrate tetrahydrate (Fisher Scientific – purity 99.0 -100 %), urea reagent (Sigma-Aldrich – purity 99.0 %). , and D-(+) glucose (Sigma-Aldrich – purity 99.5%). While other materials used such as white sugar and Saccharomyces cerevisiae yeast were commercially available in the main markets.

**1 Bioethanol production.**

**1.1 Raw Material Collection.**

Vegetable waste samples including red beetroot (Beta vulgaris), carrot, and gold potato were collected from the main local fruit and vegetable markets, located in Mosul city in Iraq, and then the samples were packed in a plastic bag and stored in the refrigerator.

## 1.2 Pre-treatment of selected samples

1 Kg of red beet, carrot, and gold potato was surface sterilized separately by sodium chloride (NaCl) solution and then rinsed well with distilled water. Each sample was peeled after washing. The remaining pulp of the selected vegetable sample was subjected to physical pre-treatment, which needed to be chopped into smaller pieces together and blended with the electric grinder, and then diluted using distilled water to 1 L (mix 1) [26-27]. Upon completion, the mixture was subjected to hydrolysis via heating up to 95°C for 2 hours to reduce the crystalline nature of cellulose aiding in the hydrolysis of lignocellulosic biomass to simple sugar. The liquid juice of each sample was cooled down at room temperature and then stored in the refrigerator for further usage [28].

## 1.3. Fermentation process

The fermentation method, according to the procedure described in Rishabh and Raj [17], was adopted and modified to produce bioethanol from vegetable wastes. Dried yeast (Baker's yeast) (Saccharomyces cerevisiae (ySR128)) (50 gm) was inoculated into 300 mL of distilled water and placed in a 500 mL conical flask under stirring conditions. Followed by 7.5 gm of urea reagent and 235 gm of sucrose (or normal white sugar) were added to the yeast mixture and then left to stir for 15 minutes at 35–40 °C for activation. Upon completion, the activated yeast inoculum and pre-treated selected vegetable waste were immediately poured into a 5 L conical flask. Distilled water was then added to the mixture to a total volume of 3 L. Lab-scale batch of anaerobic fermentation was carried out in a sealed glass vessel of an incubator that designed to conduct fermentation reactions as shown in Fig 1. During the fermentation process, S. cerevisiae converted the waste starchy source into bioethanol and carbon dioxide as released gas. In the dark condition, the fermentation of rotten vegetable waste was allowed to take place for 5 to 7 days at 32± °C with an agitation speed of 180 rpm. The alcoholic fermentation of starchy waste was stopped, once the carbon dioxide produced by the fermentation process is not vented from the fermentation chamber. It is worth mentioning that test samples were taken from fermented solution before and after the fermentation process to evaluate bioethanol production, reducing sugar and pH value.

**Fig. 1** The designed incubator designed to conduct anaerobic fermentation reactions.

## 1.4 Purification of bioethanol.

After completion of the fermentation process of bioethanol from rotten vegetables, it was purified and concentrated by using a distillation technique to maximize the alcohol percentage in the final product [29] bioethanol concentration at different stages was checked by a hydrometer at 20 °C. The distillation process (Fig. 2a, 2b) was carried out using simple and fractional distillation apparatus respectively. The percentage of bioethanol obtained was measured by a portable hydrometer to be 95%. Hydrated bioethanol was then stored over molecular sieves (3A°) overnight and the bioethanol was filtered off as filtrate to obtain the maximum percentage (anhydrous ethanol) (99%) as the final product.

(a) (b)

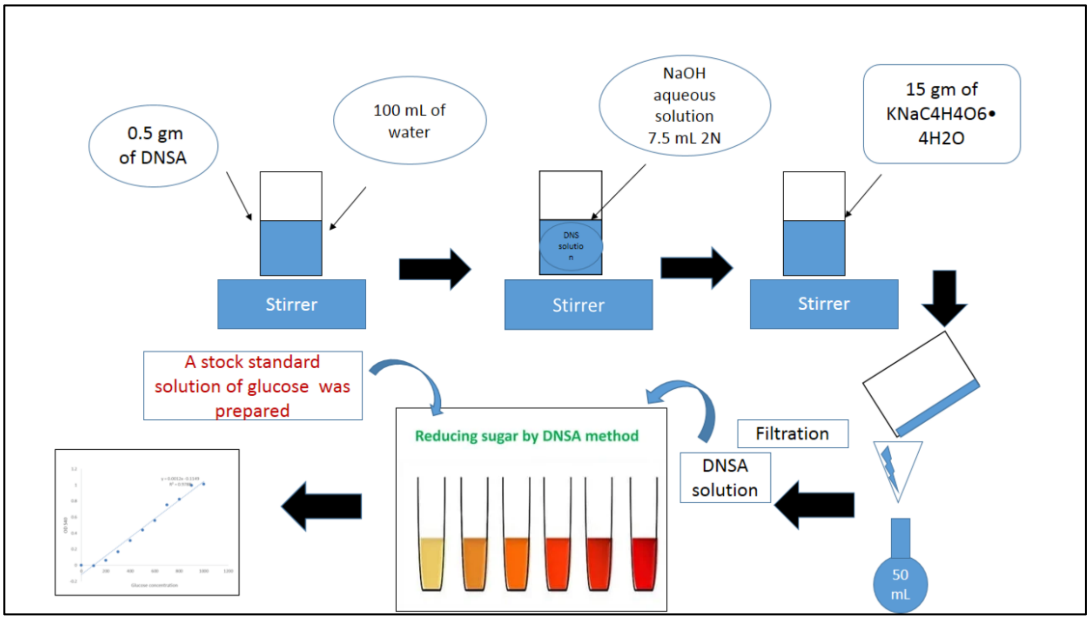
**Fig. 2** Purification of bioethanol from fermented solution via (a. simple distillation (b. fractional distillation.

## 1.5 FTIR spectroscopy.

Fourier Transform Infrared Spectrophotometer (FTIR) is a powerful technique that can be employed to determine the structural analysis of the functional group in bioethanol. In our study, the functional groups of the bioethanol from different vegetable wastes were confirmed and analyzed by using FTIR (Bruker Alpha II-ATR, Germany). The absorption frequency spectra were recorded and plotted as transmittance vs wave number. In brief, bioethanol (1.0 Micro liter- μL) was placed on a fused KBr disc, which is mounted on the cell holder and fixed on the sample beam of IR spectrometer. The running was performed over a spectrum range of 400 to 4000 $cm^{-1}$ and averaged 16 scans.

## 1.6. Determination of reducing sugars by 3, 5-dinitrosalicylic acid (DNSA) method.

The concentration of reducing sugar in the fermented solution was determined using DNSA method, which described by Garriga et al [30] with some modifications. (DNSA) the reagent was prepared by adding 0.5 gm of (DNSA) in 100 mL of distilled water, the solution was then stirred at ambient temperature. NaOH aqueous solution (2N, 7.5 mL) was slowly added to the DNSA solution and stirred at room temperature until the solution becomes clear and added. (15 gm) of Potassium sodium tartrate tetrahydrate ($KNaC_4H_4O_6 \cdot 4H_2O$) in water. The DNSA solution was filtered off using filter paper and made the volume up to 50 mL by adding distilled water in it. The solution sample was stored at a temperature below 5°C in a dark glass bottle. A stock standard solution of glucose at a concentration ranging from 0.1 mg/ mL to 1 mg/ mL was prepared and diluted to 2 mL with distilled water in each test tube. Then 1 mL of DNSA reagent was added to each tube and mixed well. The tubes were incubated at 95 °C for 15 minutes in the water bath to develop the red-brown color. After cooling, 5 mL of water was added to each test tube, and then, absorbance was measured by a spectrophotometer (UV-Vis spectrometer-PG instrument limited-Model T92+) at 540 nm. This method can be illustrated in scheme 2.




**Sheme 2** the DNSA method steps to determine the reducing sugar in unknown samples.

### 1.7. Determination of pH.

pH value of the fermented solution of vegetable wastes was determined and recorded during the fermentation process using a digital pH meter (Eutech instruments- PC 700).

## 2 Bioethanol-gasoline blend characteristic tests.

### 2.1 Sample Preparation.

Bioethanol-gasoline blended samples were prepared by mixing low octane number gasoline (RON. 82.5) with ethanol to produce the blends containing 0, 8, 10, 12, and 14 vol.%. The blending process was carried out in a glass bottle (1 L), which tightly closed under the stirring condition at room temperature for 5 minutes. All tests of bioethanol-gasoline binary blends were conducted in the department of laboratory and quality control: at Baiji refinery in Iraq.

### 2.2. Density test

The density of each tested sample was determined according to ASTM D4052 [31] using a digital density meter (Rudolph Research Analytical density meter-DDM 2911) as depicted in Fig. 3. The fuel sample was injected in digital density meters to determine the density value at 15.5 °C.

**Fig. 3** Digital density meter apparatus.

## 2.3 Reid Vapour Pressure (RVP) test.

The vapor pressure of pure gasoline and gasoline blends was measured according to the ASTM-D6378 standard [32] using a commercial RVP apparatus (Eralytics Eravap, Vapour Pressure Tester) as shown in Fig. 4. The method covers the use of automated RVP instruments to measure the vapor pressure exerted in a vacuum by hydrocarbon-oxygenate mixtures such as bioethanol-gasoline blended fuels.


**Fig. 4** Reid vapor pressure apparatus.

## 2.4 Research Octane Number (RON) test.

An octane number is considered one of the major characteristics of gasoline that must be measured accurately for motor fuels like gasoline. RON value of each bioethanol-gasoline blend was determined by a cooperative fuels research engine (Single-cylinder, four-stroke, and spark ignition engine) as shown in Fig. 5, the method was carried out according to the standard method (ASTM-D2699) [33].

**Fig. 5** Single cylinder –test engine assembly for RON measurements.

**Results and discussion.**

Three different substrates were collected and used as raw material residues including red beetroot, carrot, and gold potato for the fermentation process. After the collection of the samples, the substrates were post-treated using physical and thermal hydrolysis. The baker's yeast (Saccharomyces cerevisiae) was activated by suspending it in slightly warm water and then activated yeast was transferred and inoculated in fermentation broth containing red beet, carrot, and gold potato residues separately. The anaerobic fermentation process of vegetable residues was carried out in 5 L sealed flasks for 5-7 days at 32±2 °C at 150 rpm. Bioethanol yield was investigated at different vegetable wastes as the substrate for fermentation. Red beetroot (Beta vulgaris) waste generated the highest amount of bioethanol (7.7 %) with high purity (99%) as shown in Fig. 6, whereas carrot ranked second, followed by gold potato produced the least amount of bioethanol at the same fermentation conditions. Hence, S. cerevisiae has achieved better performance in red beetroot than the other discarded vegetables. A comparative study of bioethanol yield from potatoes via fermentation revealed that our yield was higher than previous studies, Fernando and his group [34] showed that the bioethanol yield from potatoes reached 0.6%. However, another study [35] reported that bioethanol was generated from Beta vulgaris by fermentation process in acidic conditions for a week in cold dark conditions using Saccharomyces cerevisiae. Surprisingly bioethanol yielded around 12 %.

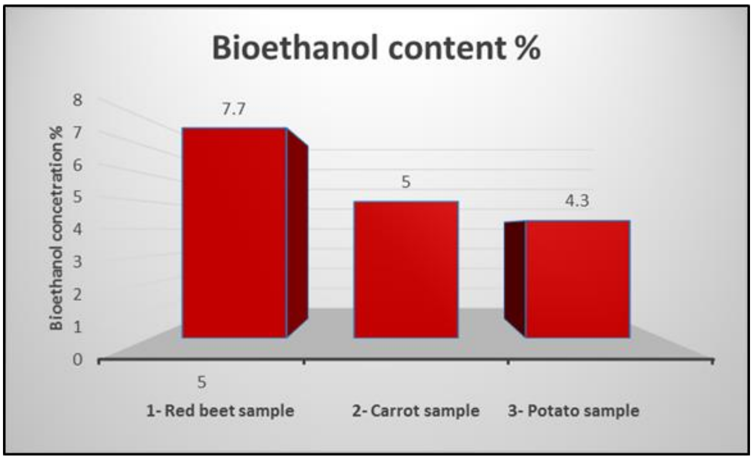



**Fig. 6** Graph showing a yield obtained of bioethanol for each vegetable waste during the fermentation process.

Many researchers have indicated that temperature also plays a main role in the fermentation process. Previous studies showed that bioethanol production improved with the increase in fermentation temperature that reached a maximum value at 35°C. However, further increasing or decreasing temperature leads to lowering the yield of bioethanol, this is probably due to the denaturing of the yeast cells used in the fermentation process [36-38]. Moreover, it can be seen that the fermentation time of different vegetable sources ranged from 5 to 7 days as illustrated in Fig. 7, the fermentation processes ended up once the bubbling carbon dioxide stopped through the airlock.

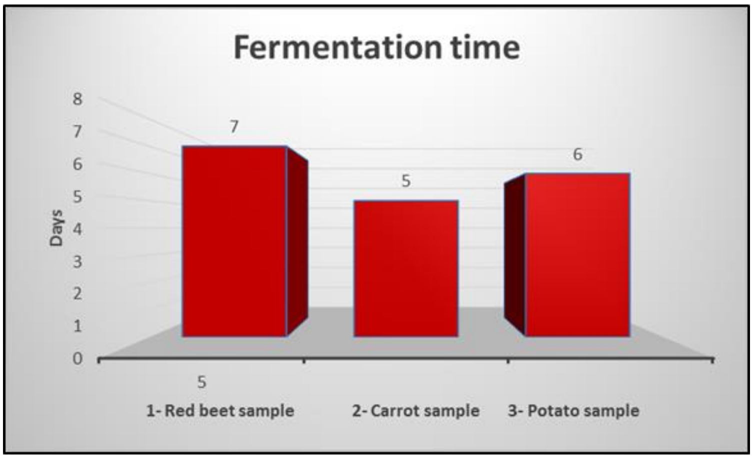



**Fig. 7** Fermentation time of various vegetable wastes using S. cerevisiae.

The maximum bioethanol productivity can be obtained depending on the type of raw material, which means that the bioethanol yield increases with high sugar or starch content in raw materials. In this work, bioethanol concentration can be expressed in terms of percentage (%). The yield percentage of ethanol was determined in the beetroot at 7.7%, and the carrot at 5.0%, whereas the potato was 4.3% as listed in Table 1 and depicted in Fig. 6. With the increase in starch content in a substrate, ethanol production increased significantly. Comparative studies of bioethanol productivity from varied decaying vegetables exhibited that beetroot waste had higher efficiency compared to other vegetable wastes. Therefore, the fermentation process of this waste is cost-effective and does not produce any toxic by-products. Hence, it could be potentially applied on a large scale for industry.

**Table 1:** Various parameters obtained during vegetable waste fermentation.

| Sample | pH value before fermentation | pH value after fermentation | Bioethanol % | Fermentation period (days) |
|---|---|---|---|---|
| Red beetroot | 6.4 | 5.4 | 7.7 | 7 |
| Carrot | 7.2 | 5.4 | 5.0 | 5 |
| Potato | 7.1 | 5.7 | 4.3 | 6 |

(Fig. 8) showed that the pH parameter has a considerable influence on the alcoholic fermentation process. Based on this work, the initial pH of bioethanol obtained from the selected waste vegetables was determined to be between 6.4 to 7.2, while the final PH value of bioethanol obtained was determined in the beetroot at (5.4), carrot (5.4), and potato (5.7). It was noted that the pH value was slightly decreased after yeast fermentation; this can be due to the conversion of glucose to bioethanol. In terms of yeast activity, yeast can survive in acidic conditions that ranged from 4 to 6 [27]. Another study indicated that the optimum pH value for yeast fermentation to generate bioethanol is 4.5 [39].

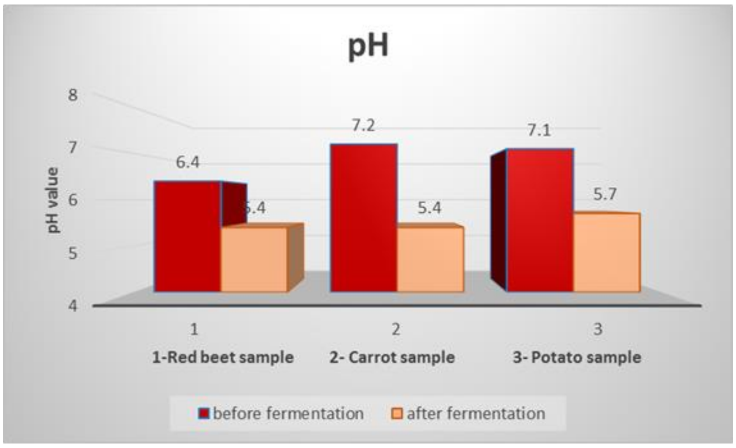
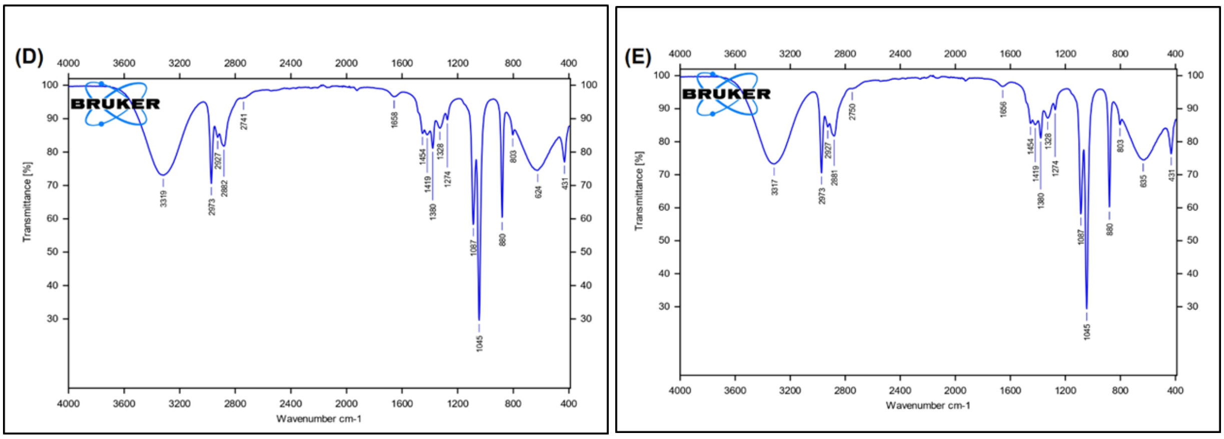



**Fig. 8** Graph showing a pH obtained of fermented solution for each vegetable waste during the fermentation process.

After purification and collection of bioethanol from each fermentation process, FTIR spectroscopy analysis has performed on samples, it identified the presence of methyl (-$CH_3$) stretch, hydroxyl (-OH) stretch, and –alkane (-$CH_2$) stretch in pure bioethanol. In the FTIR spectra (Fig. 9 D, E, and F) of each sample, a broad absorption band was found in a wave number range of 3317 to 3331 $cm^{-1}$ (slightly different in root beet, carrot, and potato), which corresponds to the OH stretching vibrations. Another peak is assigned at 2973 $cm^{-1}$ as a sharp peak of stretching vibration due to the presence of the methyl group. Previous studies confirmed that wave numbers 2,900 and 3,300 $cm^{-1}$ in FTIR graph of ethanol have been linked to C-H and O-H molecule groups, respectively [40, 41]. Notably, absorbance bands between 1045 $cm^{-1}$ and 1380 $cm^{-1}$ were observed due to stretching bands of the C-O functional group [40].



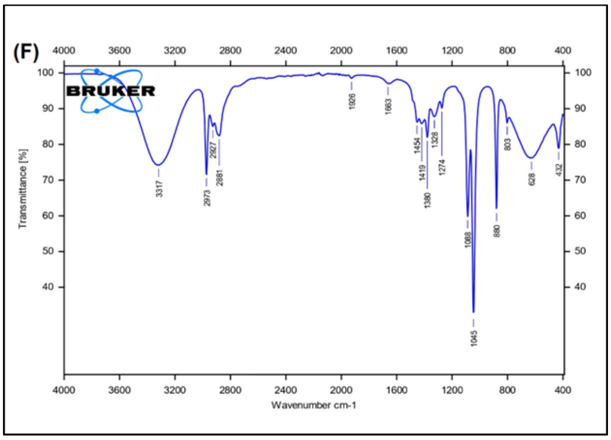



**Fig. 9** FTIR spectra of distilled bioethanol, which produced from (D) beetroot waste, (E) carrot waste, and (E) potato waste.

The standard curve of stock solution glucose was plotted to determine the reducing sugar and compared to each sample. The amount of sugar content was assessed using DNS reagent and it was found to drop down remarkably during the fermentation process. The sugar content of overripe vegetable extracts was determined by comparing their absorbance taken from each sample to the standard curve of reducing sugar to calculate the sugar content at A 540. Among the three decaying vegetable extracts used for the analysis of reducing sugar content, glucose content in beetroot solution extract dropped from 0.58 to 0.44 (mg/ mL) after 7 days (Fig. 10) of fermentation, whereas glucose level in carrot started from 3.4 (mg/ mL) at the beginning of fermentation to 0.86 (mg/ mL) at 5 days. A similar trend was observed in potatoes, glucose level in potatoes waste declined from 3.7 (mg/ mL) to 0.40 (mg/ mL) after 6 days of fermentation. The reduced sugar concentration declined as the fermentation proceeds owing to the consumption of the sugar by Saccharomyces cerevisiae cells to produce bioethanol and carbon dioxide.

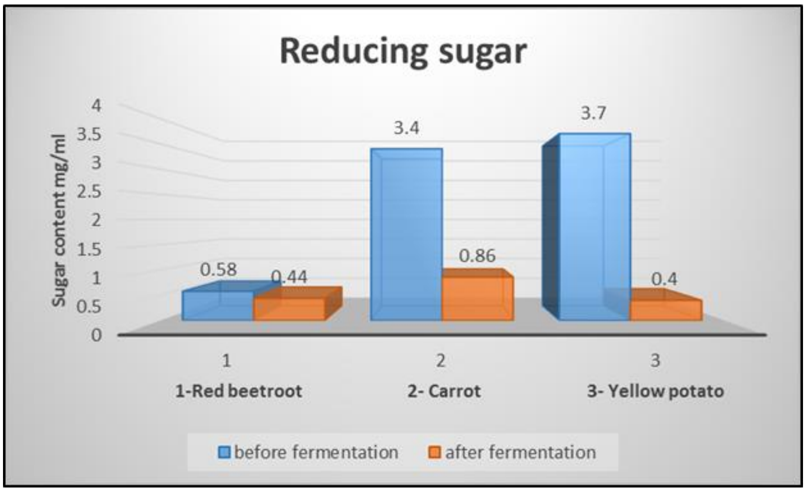



**Fig. 10** Estimation of sugar content in decaying vegetable extracts before and after fermentation.

The present study also focused on conducting tests toward bioethanol-gasoline blend characteristics and performance in different bioethanol ratios to analyze the probability of these blends as an alternative fuel. Therefore, different blend rates of bioethanol–gasoline blended fuels (3%, 5%, 7%, 9%, 11%, 13%, and 15%) were prepared and then sent to the petroleum quality control laboratory at Baiji refinery for ASTM standard analysis. The main results obtained from the ASTM analysis including RVP, density, and RON have been summarized in Table 2, to show the effects of bioethanol addition (3%, 5%, 7%, 9%, 11%, 13%, and 15% by volume) to gasoline on its performance. The results showed the variations of density (g/cm3), RVP (psia), and RON, which considered as a function of different blend rates of bioethanol–gasoline mixtures.

**Table 2**: Specifications of regular gasoline and bioethanol-gasoline blends.

| Characteristics | Test Method (ASTM) | Base gasoline | Bioethanol ratio in the fuel | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 3% | 5% | 7% | 9% | 11% | 13% | 15% |
| Density (g/cm$^3$ at 15.51C) | *ASTM-D4052* | 0.7305 | 0.7332 | 0.7334 | 0.7344 | 0.7353 | 0.7369 | 0.7377 | 0.7395 |
| RVP ( psia at 37 C) | *ASTM-D6378* | 10.40 | 10.30 | 10.30 | 10.30 | 10.33 | 10.20 | 10.18 | 10.0 |
| RON | *ASTM-D2699* | 82.5 | 82.8 | 84.2 | 85.4 | 87.5 | 87.8 | 89.0 | 89.0 |
| Color | yellow | yellow | Yellow | yellow | yellow | yellow | yellow | Yellow | yellow |

(Fig. 11) represents the density values (g/cm3) of the base gasoline and gasoline blends with bioethanol at various rates. The graph indicated that density increased with increasing the bioethanol content in the gasoline blend. The result is quite common due to the density of bioethanol that higher than the base gasoline.

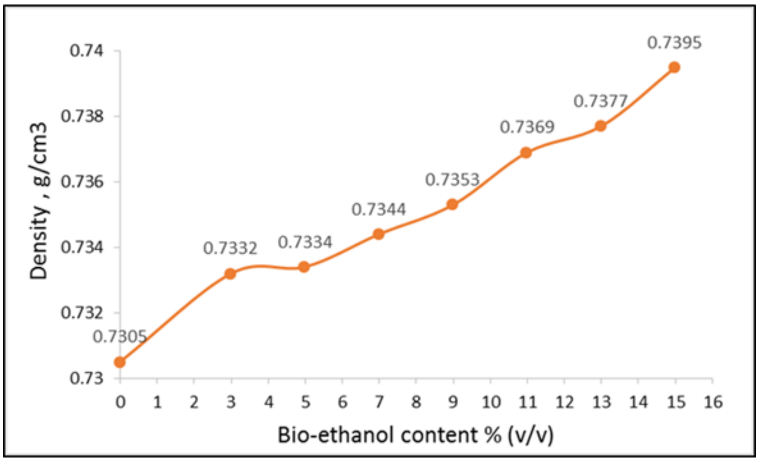



**Fig. 11** Graph showing density vs bioethanol content ratio to gasoline.

The behavior of bioethanol-gasoline mixtures was significantly different from conventional gasoline even though the RVP value of ethanol is much lower than that of base gasoline. The RVP value declined slightly when bioethanol was added to regular gasoline in various ratios as depicted in Fig. 12. The decrease of RVP from fuel blends is caused by the little amount of water in the bioethanol-gasoline mixture by the increase of the volume of the alcohol mixture, and it may cause gasoline blend volatility change (water is more difficult to evaporate compared to gasoline and alcohol) [41].

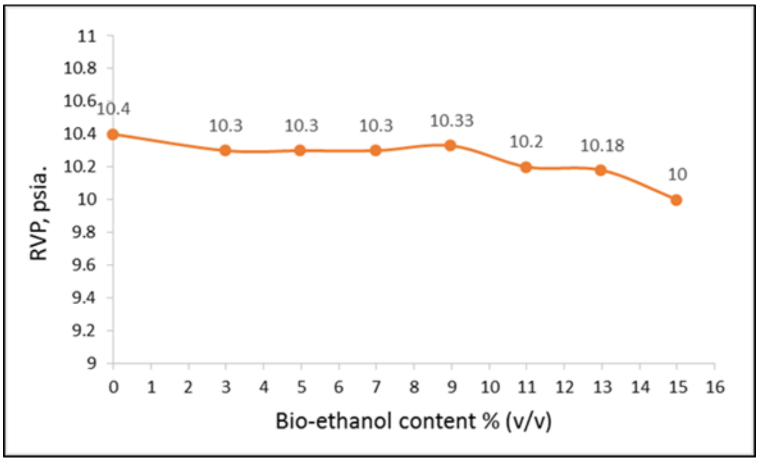



**Fig. 12** Graph showing RVP vs bioethanol content ratio to gasoline

From the results of ASTM-D2699, RON of samples varies from 82.5 to 89 depending on the volume % of bioethanol added to the sample. The RON increases progressively with the increase of ethanol content as depicted in Fig.13, because of having a high RON value of pure ethanol at 105. It can be observed that the RON value jumped around 7 points when the bioethanol content exceeded 13% by volume, RON of blended fuel did not increase with increasing the bioethanol content to 15% by volume. Therefore, there is no need to increase ethanol content above 13% as it has a negative impact on RON parameter. The result obtained coincided with another study that investigated the impact of a gasoline-bioethanol mixture on the value of gasoline's octane number [42].

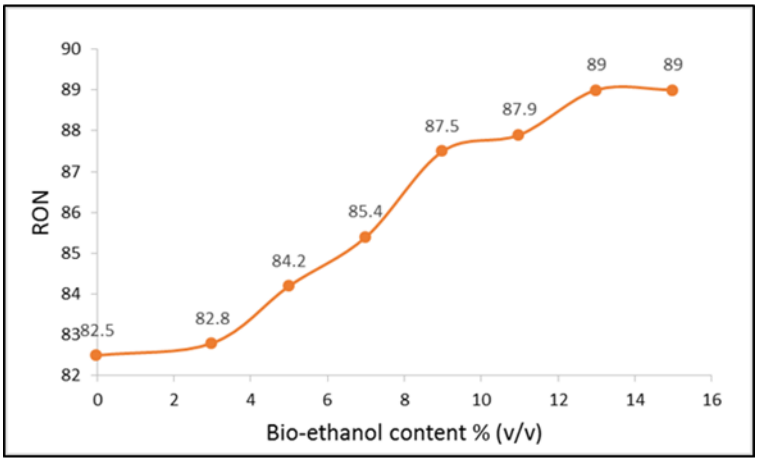



**Fig. 13** Graph showing RON vs bioethanol content ratio to gasoline.

## 4. Conclusions

In the present work, the results obtained revealed that different decaying vegetables could serve as raw materials for bioethanol production via the bioconversion process. Furthermore, alcohol produced can be blended with normal gasoline (RON-82.5) in various ratios to be used as an alternative fuel to mitigate the demand for conventional fossil fuel resources. From this comparative study, the maximum bioethanol yield was obtained from beetroot waste (7%) followed by carrot waste (5%) then potato waste (4.3) at 32 °C in acidic conditions (pH 5-6). The S. cerevisiae (yeast) was utilized to convert saccharide wastes into bioethanol and carbon dioxide, then a high concentration of bioethanol was obtained via simple distillation, fractional distillation, and dehydration respectively. Bioethanol was mixed with conventional gasoline to produce blends that can be used as an alternative fuel for variable speed spark ignition up to 10 vol. % blends without engine modification. Analytical and experimental work on a single-cylinder engine was conducted to evaluate the effect of using bioethanol-gasoline blends instead of the base gasoline on the RON value, which considered a critical fuel property that plays a primary role in the design of the engine. It was clear that gasoline with ethanol content until 13% (v/v) can boost the RON value by 7 more points compared to base gasoline. These blends can be. used by the vehicle engine smoothly without any engine modification. The comparative study showed that adding bioethanol to gasoline in different proportions has affected slightly on PVP and density values of blended fuels compared to regular gasoline. It can be concluded that gasoline with 13 % (v/v) bioethanol content can work well as a premium gasoline substitution.

**Conflicts of interest.**

The authors declared that there is no conflict of interest.

**Acknowledgments**

We gratefully acknowledge Mosul Uniersity-Iraq for its support of this work. The present study was performed in the research center of the chemistry department at Education College for Pure Science. Furthermore, Gasoline blended samples were sent to the petroleum quality control laboratory: Baiji refinery in Iraq, to characterize and analyze their properties.

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# انتاج الايثانول الحيوي من عملية التخمير باستخدام مخلفات الخضروات كمادة أولية لانتاج مزائج الكازولين-الايثانول كوقود بديل

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**الكلمات المفتاحية:**
*الايثانول الحيوي، التخمير، العدد الاوكتاني البحثي*

**معلومات المؤلف**

الايميل:
الموبايل:

**الخلاصة:**

العمل الحالي هو للتحقق من انتاج الايثانول المحتمل من مخلفات الخضروات المحلية كمادة أولية خلال عملية التخمير. وقد خضعت هذه المخلفات الى عملية معالجة مسبقة قبل عملية التخمير. عملية تحويل الكتلة الحيوية تمت باستخدام مواد أولية وخميرة جافة غير مكلفة مثل (Saccharomyces cerevisiae) ولمدة تراوحت من 5 الى 7 أيام. ان الغاية من البحث تقدير نسبة الايثانول المنتج من المخلفات. الى جانب ذلك، محاليل التخمير تمت تقييمها وتحليلها باستخدام عوامل مختلفة المتضمنة قيمة الدالة الحامضية، محتوى السكر، والحصيلة خلال التخمير عند درجة 32 م° لإنتاج الكحول. وقد لوحظ ان محتوى السكر قد انخفض للمواد الأولية خلال عملية التخمير. في حين ان الدوال الحامضية قد انخفضت خلال التخمير. مخلفات الخضروات المتضمنة الشمندر، الجزر والبطاطا قد سجلت اعلى نسب إنتاجية للإيثانول بنسب 7.7%, 5%, و4.3% على التوالي. هذا البحث يظهر طريقة واعدة لإنتاج الايثانول الحيوي على المستوى الصناعي باستخدام مخلفات عضوية وخميرة رخيصة. علاوة على ذلك، يتم مزج الايثانول المستحصل مع الكازولين الاعتيادي لإنتاج مزائج الكازولين الكحولي بنسب مختلفة 0%,3%,5%,7%,9%,11%,13.%15%. تم تقييم بدائل الوقود الممزوج مختبريا باستخدام الطرق الامريكية القياسية لاختبار المواد. اذ تم قياس مواصفات مزائج الكازولين –الايثانول المتضمنة ضغط ريد البخاري، الكثافة، والعدد الاوكتاني البحثي تبعا للطرق الامريكية القياسية. وقد استخدم محرك بأسطوانة واحدة لدراسة تأثير مزائج الكازولين الكحولية على أداء المحرك. بالشكل العام، أظهرت النتائج ان العدد الاوكتاني البحثي قد تحسن بشكل ملفت للنظر مع زيادة محتوى الايثانول في مزائج الكازولين.