

USING WASTE PAPER AS A PROMISING FEEDSTOCK FOR BIO-ETHANOL FUEL PRODUCTION WITH CONSEQUENCE PURIFICATION USING DISTILLATION TECHNIQUE AND MOLECULAR SIEVE

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Received 02.04.2024

Accepted 27.06.2024

Abstract: In the present study, office waste paper was employed as feedstock for bioethanol production. Lignocellulosic material was pre-treated with dilute sulphuric acid (5 %) to release monomeric sugars. Acid pretreatment of waste papers was carried out at different ratios of 10, 15, and 20 ml for each 1 gm of raw material to obtain the best yield of hydrolysate. After the pH adjustment of each paper hydrolysate, the hydrolysate was subjected to fermentation and distillation processes respectively. The fermentation process was performed using *Saccharomyces Cerevisiae* to convert the released sugars to bio-ethanol as a main product. The highest bio-ethanol yield (28.3%) was obtained at a high concentration from the yeast fermentation using waste paper pretreated with acid at a ratio of 10:1 ml/gm (liquid to solid). Economically, office waste paper is a suitable raw material for sustainable bio-ethanol production. Furthermore, bio-ethanol obtained was blended with pure gasoline at increasingly higher concentrations. A gasohol was homogeneously mixed with four formulated fuels such as gasoline blend (E0), gasoline–5% bio-ethanol blend (E5), gasoline–10% bio-ethanol blend (E10), and gasoline–15% bio-ethanol blend (E15). It is critical to investigate the effect of various bio-ethanol blends on the characteristics and performance of internal combustion fuel. These binary mixtures were tested using density, Reid vapor pressure (RVP), and Research Octane Number (RON) tester according to the ASTM-D4052, ASTM-D6378, and ASTM-D2699 respectively under selected operating conditions. The results obtained revealed that the addition of gasoline–bioethanol blend decreases the RVP value of the fuel blend, whereas the RON and density increase because bioethanol has a high octane rating compared to conventional gasoline, resulting in enhanced gasoline's performance in internal combustion engines. Overall, the RON of gasohol was enhanced remarkably with the increase in ethanol ratio.

Keywords: Bioethanol; fermentation process; *Saccharomyces cerevisiae*; Paper wastes.

DOI: 10.32737/2221-8688-2025-1-20-35

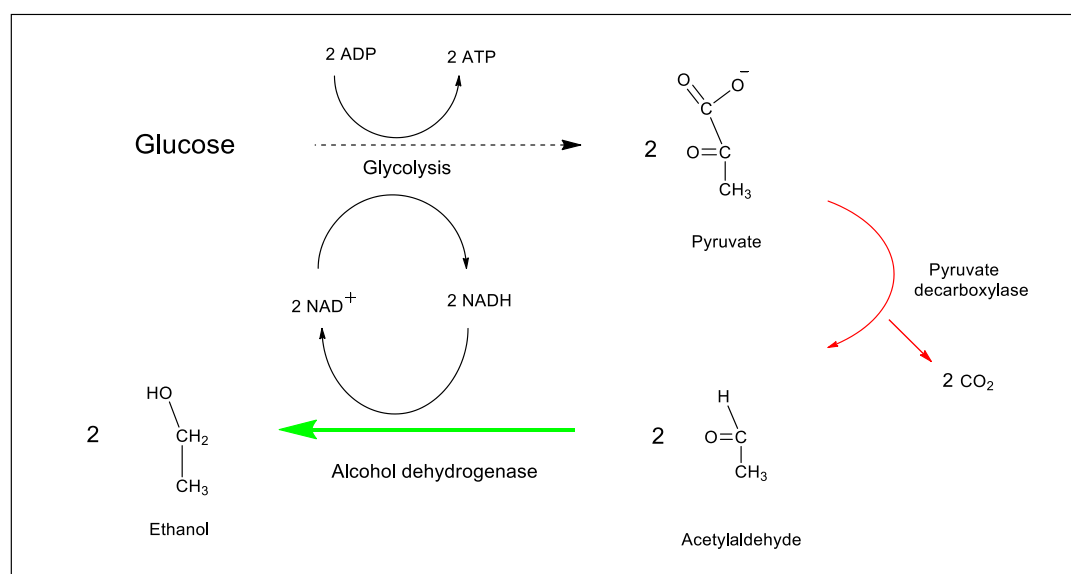
1. Introduction

The population increase and economic growth have led to more consumption of materials and resources to meet the global demand for high-quality services and goods. Nevertheless, the material consumption levels have tended to increase the number of waste materials, such as municipal solid waste, paper wastes, and industrial wastes [1]. These biomass wastes can be invested for the production of valuable products such as low-cost biofuels [2]. Emerging of ethanol production from lignocellulosic biomass is one of the most impressive technologies for sustainable production of fuels. Most of the fuel ethanol

produced is currently coming from starchy or saccharide biomass sources [3, 4], which are required by human beings and livestock for nourishment, this has led to creating a critical competition between food security and energy [5]. However, the alcohol production technology from non-food plant sources is attractive and being developed remarkably, so commercial production will be a reality soon [3]. Production of bio-ethanol from lignocellulosic biomass or wastes as second generation has many advantages compared to ethanol production from food crops as first generation [6]. The cellulosic feedstocks, such

as industrial waste and agricultural residue, are the most cost-effective and abundant renewable sources. The second-generation biomass can be employed to produce bio-ethanol from mixed paper waste, which is separated from the municipal solid waste and open dumps [7]. This lignocellulosic waste contains a major and underutilized supply of sugar/cellulose, which can be transformed into ethanol and utilized as fuel, resulting in environmental and energy advantages. Bioethanol can be generated from various residues and waste papers to address these issues [5]. One of the most abundant and cheap lignocellulosic sources is paper waste. Globally, 500 million tons of paper and cartons are produced per year, the vast majority of paper products end up in landfills or burned as garbage while a low percentage of this material is recycled and utilized as a sustainable source for paper production or fuel. Paper waste burning from municipal solid waste mainly contributes to greenhouse gas emissions and releasing of toxic substances, which associated with global warming phenomena and climate

change impacts [5, 8]. Recycling discarded paper into useful biomaterials is an effective approach to disposal to minimize accumulated paper waste [9]. Paper wastes as second generation are relatively abundant and economically competitive with other biomass sources, this is due to low costs and containing high levels of carbohydrates, which can be potentially converted into bio-ethanol; these wastes are possibly to be easily digestible without more aggressive chemical or physical pre-treatments, which accelerate the lignocellulosic wastes biodegradability. Under anaerobic conditions, the metabolic pathway of alcoholic fermentation (Scheme 1) occurs in two main steps: The first step involves the breaking down of glucose into two pyruvate molecules in a process called glycolysis. Followed by the second step which involves the decarboxylation of pyruvate to acetaldehyde pyruvate decarboxylase with releasing two carbon dioxide molecules and the subsequent reduction of acetaldehyde to two bioethanol molecules by alcohol dehydrogenases [10].



Scheme 1. Mechanism of alcoholic fermentation

Conversion of waste papers into bio-ethanol fuel may suggest a useful and valuable alternative approach to managing these wastes and complement to recycling process [6]. Recent studies have been carried out to maximize bio-ethanol production and investigate the conversion of biomass into bio-ethanol using different pretreatment processes, with a focus on newspaper wastes [11, 12],

cardboard wastes [13, 14], and office waste papers [15-17]. Bio-ethanol is considered one of the most important alternative sustainable energy sources that replace conventional fuels (fossil fuels) due to its potential to mitigate negative environmental effects such as air pollution [18, 19]. It is a liquid environmentally friendly fuel, which considered as most promising alternative fuel instead of gasoline.

The environmental impact of bio-alcohol is less compared to conventional gasoline due to its high oxygen content [20], using ethanol-gasoline blended fuel as known (gasohol) can remarkably reduce carbon mono oxide (30–37%) and hydrocarbon emissions (19–28%) [21]. Blending gasoline with ethanol as fuel reduces greenhouse gases significantly compared to traditional gasoline and produces environmental gasoline. Many researches have been conducted on gasohol to find the appropriate amount of ethanol. Various blends have been made to determine the optimum amount of ethanol that should be utilized [22–24]. The main general category of gasohol is E10, which contains ethanol 10% as an additive to 90% gasoline, resulting in 12–25% less exhausted gas emissions of carbon monoxide [20]. Moreover, it can improve the octane rating of gasoline especially when blended with it by a certain ratio compared to conventional gasoline [19].

The key novelty in this work is the utilize of office waste paper as raw material for

alcoholic fermentation, and few studies investigated the productivity of waste paper for bio-ethanol. For first time, acid pretreatment is conducted using refluxing process instead of autoclave and obtain high ethanol yield. Furthermore, bio-ethanol obtained was mixed with gasoline as enviromental fuel and analyzed for internal combustion engines. In this way, bio-ethanol can be produced inexpensively usinga feedstock that is otherwise thrown away.

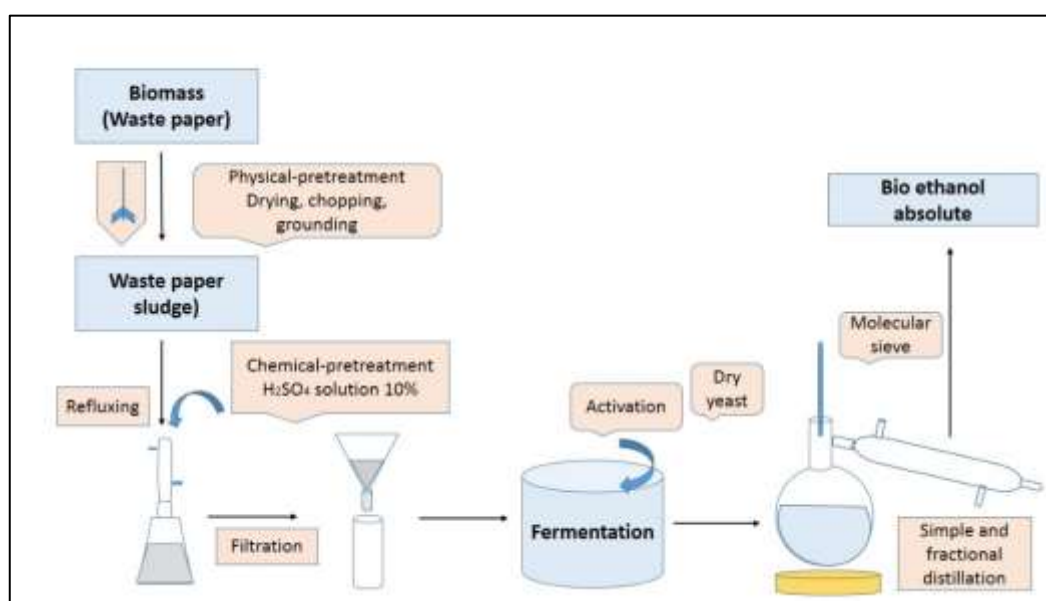
Current research mostly involves the production, purification, and characterization of bio-ethanol from waste paper then blending with pure gasoline to produce ethanol-gasoline blends to enhance the gasoline for a spark-ignition engine, it aimed to convert the office paper wastes as cheap sources to bio-ethanol fuel via anaerobic fermentation process using microorganisms (*S. cerevisiae*) at specific conditions. Acid pre-treatment is applied before biochemical fermentation reactions, followed by bio-ethanol purification using a distillation technique to obtain high-purity ethanol for fuel purposes.

2. Experimental part

2.1 Materials.

All the chemicals and reagents were provided by Sigma-Aldrich, and Fisher Ltd and used as received without further purification such as 3, 5-dinitro salicylic acid (DNSA), D(+)

glucose sodium potassium tartrate, urea reagent, and sulfuric acid. *Saccharomyces cerevisiae* yeast (E 491) and 3A° molecular sieve (Moisture Boss) are commercially available in the local markets.



Scheme 2. Main steps of pure bio-ethanol production from office paper waste as feedstocks

2.2. Procedures.

2.2.1 Bio-ethanol production. The main processes of bio-ethanol production from waste papers include three main steps: (1) collection and pre-treatment of the waste; (2) converting cellulose to ethanol by fermentation after activation of yeast; (3) ethanol separation and purification. These stages can be described in Scheme 2.

Collection and preparation of paper wastes. Office waste papers were gathered locally in Mosul University, the wastes were employed as a feedstock in this current study. After collection, the paper wastes were transferred to the laboratory and placed in the oven using a tray drier at 90 °C for 24 hours in

order to ensure equilibrium moisture content. After measuring the moisture content, the dried feedstock was stored in a desiccator until the next stage.

It is worth mentioning that the office waste papers (feed-stocks) were analyzed biochemically by Guerfali and his group [25], and it was found that the waste paper possesses high cellulose content (long chains of glucose linked by (β -1, 4) via glycosidic bonds) and a very low hemicellulose and lignin content as presented in Table 1. This feature is more suitable for fermentable sugar production because there will be less physical barrier during the enzymatic hydrolysis of cellulose fractions.

Table 1. Office waste paper ingredients (%) [25].

	Waste paper ingredient (content %) ^a						Reference
	Moisture	Cellulose	Hemicellulose	Lignin	Ash	Others	
Office paper	3.2	78.6	4.7	1.2	9	3.3	This work

Mechanical pre-treatment. The dried raw materials were cut into small pieces of 0.5 cm x 0.5 cm size. Grinding was carried out using the electrical mixer with water to obtain waste paper sludge, followed by drying to afford dried feedstock. The physical pre-treatment would decrease cellulose crystallinity and increase the surface area of the sample [26], which improves the contact between dilute acid with cellulose and hemicelluloses.

Chemical pre-treatment. The acid hydrolysis procedure of the waste paper was described according to modified literature by Awol [18]. This step was performed to break down cellulose into glucose units. The office

paper wastes were subjected to acid pretreatment with sulphuric acid at various volume ratios (1:10, 1:15, and 1:20 wt/v) and a concentration acid solution of 5% (v/v).separately, as listed in Table 2. The resultant mixture was heated up to reflux for 3 hours of treatment time, and then the hydrolysate was cooled down to ambient temperature and filtered using Whattmann filter paper to collect the solid residues as sludge, then washed with distilled water many times until reaching pH = 4 to 4.5. The influence of the feedstock/acid ratio was investigated to find out the optimum conditions to produce ethanol.

Table 2. Experimental results of acid pre-treatment for paper wastes.

Sample	Acid concentration (%) of pre-treatment	Acid solution to waste paper ratio (mL/gm)	Treatment time (hour)C
1	5	10	3
2	5	15	3
3	5	20	3

2.2.2 Fermentation and distillation

Fermentation process. The bio-ethanol

fermentation procedure was adopted according to the literature-modified procedure [19]. Dried

yeast (*Saccharomyces cerevisiae* (E 491)) (25 gm, 1%) was activated into 150 ml of sugar solution under stirring conditions. Followed by the addition of 3 gm of urea reagent to the yeast mixture and then left to stir for 15 minutes at 35–40 °C for activation. Upon completion, the suspension yeast form was carefully added and mixed with the sludge, which obtained from the acid pre-treatment step. The resulting suspended mixture was placed in 5 L of conical flask and diluted to 3L of distilled water, then fermented in the absence of oxygen. The anaerobic fermentation was performed at 30 C for 3 days with an agitation speed of 180 rpm. The pH of the fermented solution was adjusted to be 4.5. pH value was monitored using a digital pH meter (Eutech instruments- PC 700).

Purification of targeted product. After fermentation completion, the bio-ethanol product was separated from the fermented solution using a distillation technique following the method described by Chen and his group [27]. The specific gravity of alcohol was checked by hydrometer to determine the percentage concentration of bio-ethanol. The

distillation process was optimized accordingly to obtain the maximum percentage of alcohol as the final product. The simple and fractional distillation processes were performed between 78 –80 °C respectively, in order to obtain high purity bio-ethanol (90%). Furthermore, it was dried using a 3A° molecular sieve to afford anhydrous ethanol (absolute, 99%) that measured by hydrometer. The dry agent plays a main role to obtain anhydrous bio-ethanol; it is attributed to the pore volume of molecular sieve. The pore size is large enough to allow water molecules to be absorbed through and blocked of ethanol into the beads. Consequently, The water molecules saturate the beads, while the dry bio-ethanol passes through the system bead [28].

Bio-ethanol produced was analyzed and confirmed by using FTIR analysis (Bruker Alpha II-ATR, Germany) and ¹H NMR spectroscopy (Bruker, 500 MHz, Germany). The amount of ethanol obtained was measured using a glass cylinder to calculate the ethanol yield from the feedstock using the following equation:

$$\begin{aligned} \% \text{ Bioethanol } \left(\frac{\text{wt}}{\text{wt}} \right) &= \\ &= \frac{\text{volume of bioethanol obtained (ml)} \times \text{density of ethanol (0.789 gm/ml)}}{\text{weight of feedstock (gm)}} \\ &\times 100 \end{aligned}$$

Estimation of Sugar content. Reducing sugar values of fermented samples were evaluated following the modified procedure as described by Garriga et al [29]. 3,4-Dinitrosalicylic Acid (DNSA) reagent was prepared by adding 0.5 gm of DNSA and 15 gm of sodium potassium tartaric acid ($\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$) to 40 ml of 0.5 N NaOH solution. The resulting solution was kept at 45°C until the solution became clear and then cooled down to ambient temperature. The solution was diluted with distilled water to 50 ml using a volumetric flask. The resultant solution was stored at 5°C in a dark glass bottle. A glucose standard solution at a concentration ranging from 0.1 to 1 mg/ml was prepared using dried test tubes, and then standard solutions were diluted to 2 ml with distilled water in each tube. Following by addition of 1 ml of DNSA

reagent to each tube, then the solution is mixed and covered. All test tubes were incubated at 95 °C for 15 minutes to develop the red-brown color. After cooling, distilled water (5 ml) was poured into each test tube to stabilize the color. Thereafter, absorbance was measured by a spectrophotometer (UV-Vis spectrometer-PG instrument limited- Model T92+) at 540 nm.

2.2.3 Characteristic tests of bioethanol-gasoline mixture.

Sample preparation. Gasohol samples were prepared by mixing normal gasoline with high-purity bio-ethanol (99%) in various blended rates (0%, 5%, 10%, and 15% (vol/vol). The blending process aims to find out the optimum volume percent of alcohol added to gasoline to upgrade its physico-chemical properties. Then experimental tests for the various gasohol samples were applied to

determine the physicochemical characteristics including, Reid vapor pressure, density, Research octane numbers (RON), GC-mass analysis (PIONA), and water content. Furthermore, the optimum oxygenated sample has been selected as an environmental gasoline sample with the optimum percentage of ethanol. All tests of bio-ethanol-gasoline binary blends were conducted in the department of laboratory and quality control: at Baiji refinery in Iraq.

Density test. The density is one of the main standard tests applied for crude oil and its products. The density of the sample was determined according to ASTM D4052 [30] using a digital density meter (Rudolph Research Analytical density meter-DDM 2911). The ethanol-gasoline sample was injected in digital density meters to determine the density value at 15.5 °C.

Reid Vapour Pressure (RVP) test. RVP evaluates the vapour lock tendency occurring in a spark ignition engine operated with fuel such

as gasoline and ethanol-gasoline blend in which excess vapours generated in line cause an interruption in liquid fuel supply to the engine. It is considered an important tool to evaluate the hazard degree of fuel. The vapor pressure of pure gasoline and gasohol was measured according to the ASTM-D6378 standard [31] using a commercial RVP apparatus (Eralytics Eravap, Vapour Pressure Tester).

Research Octane Number (RON) test. Research octane number (RON) is one of the major characteristics of fuel that must be measured accurately for motor fuels like gasoline. RON measures the performance of an internal combustion engine at normal conditions and low speed that reaches 600 rpm. RON value of pure gasoline and gasohol samples were estimated by a cooperative fuels research engine (Single-cylinder, four-stroke, and spark ignition engine). This method was performed according to the standard method (ASTM-D2699) [32].

3. Results and discussion

The focus of this study is to produce bio-ethanol from office paper wastes by acid pretreatment and subsequent alcoholic fermentation. A set of experiments were conducted to determine the optimum condition to produce bio-ethanol from office waste papers. The yield percentage of ethanol was determined in the waste paper (10:1, liquid to solid ratio) at 28.3%, and the waste (15:1, liquid to solid ratio)

at 24.2%, whereas it was 22.3% for the waste when pretreated with the acid solution at 20:1 as listed in Table 3 and depicted in Fig. 1. The results obtained suggest that the ethanol productivity depends on the effect of acid concentration and paperweight in the pretreatment step. Moreover, the fermentation parameters and purification technique also affect the purity and yield of bio-ethanol.

Table 3. Experimental results obtained of acid pretreatment and fermentation parameters

Sample	Acid solution (5% H_2SO_4) to waste paper ratio (mL/gm)	Treatment time (hour)	pH value	Ethanol yield (%)	Fermentation period (days)
Sample 1	10	3	4.6 ^b -4.5 ^a	28.3	3
Sample 2	15	3	4.7 ^b -4.5 ^a	24.2	3
Sample 3	20	3	4.8 ^b -4.6 ^a	22.3	3

*a: it expresses to pH value after a fermentation process, b: it refers to pH value before the fermentation process.

After acid pre-treatment at different ratios, the anaerobic fermentation process of waste papers was performed using *S. cerevisiae* for 3 days at 32 °C, which produced bio-ethanol. It is worth noting that *S. cerevisiae* was employed in the alcoholic fermentation under anaerobic

conditions, selection of this type of yeast is due to high ethanol productivity, high yield, and high tolerance to several environmental stress factors, such as ethanol, low pH, and low oxygen. Furthermore, yeasts in general are insensitive to bacteriophage infection so yeast

can be used at the industrial level to produce bioethanol with a yield close to the theoretical maximum (0.51 g ethanol per g of consumed glucose) [33].

Many researchers reported that fermentation temperature plays a main role in anaerobic metabolism. Previous studies revealed that bio-ethanol productivity can be enhanced with the increase of fermentation temperature that reached a maximum value at 35°C. However, further increasing or decreasing temperature may lead to lowering the yield of ethanol production; this can be due to the denaturing of the yeast cells used [34-36]. It can be noted that the maximum amount of bio-ethanol obtained was 28.3 % at a pre-treatment ratio of 10:1 as shown in Fig. 1, whereas bio-ethanol yield percentage of waste paper, which treated with acid (15:1), ranked second,

followed by bio-ethanol produced from paper wastes when pre-treated at 20 ml/g with the acid solution at the same fermentation conditions. A comparative study of yeast fermentation of the present work showed a good agreement with the previous studies, it revealed the maximum bio-ethanol productivity from the yeast fermentation process of office waste papers was 19.5 % after pre-treatment of feedstock with sulphuric acid (5%) at 10:1 (acid to waste paper ratio) for 1 hour [15]. However, another study found that the highest conversion of waste paper to bio-ethanol was 2.2 ml/10 gm after the acid pre-treatment process at 20 ml/g (liquid to solid ratio) for 2 hours of treatment [18]. During the fermentation process, high ethanol productivity can be achieved using *S. cerevisiae* with a yield that may reach 0.51 g ethanol per g of consumed glucose (51%) [33].

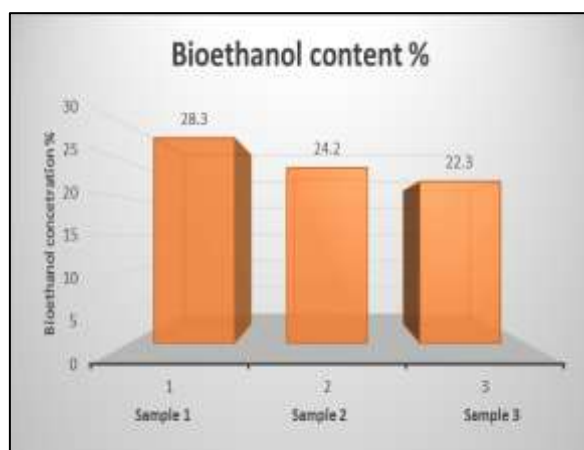


Fig. 1. Graph showing a bio-ethanol yield of waste papers that chemically pre-treated during the anaerobic fermentation process

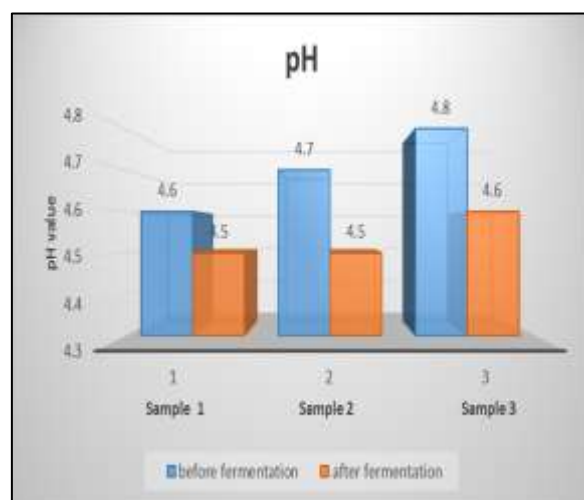


Fig. 2. pH value before and after fermentation of different waste paper samples.

It can be seen (Fig. 2) that the pH values have smoothly dropped and become more acidic during the alcoholic fermentation processes. In this current study, the initial pH values of fermented solution of sample 1, sample 2, and sample 3 were measured to be 4.6, 4.7, and 4.8 respectively, while the final pH values of solutions during anaerobic fermentation were determined in the sample 1 at (4.5), sample 2 (4.5), and sample 3 (4.6). It can be noted that the pH values were slightly decreased after yeast fermentation; this is due to the lactic acid formation during the metabolism pathways of yeast fermentation [37]. In terms of yeast

activity, *S. cerevisiae* can survive in acidic conditions that range from 4 to 6 [38]. Another study revealed that the optimum pH value for high bio-ethanol proactivity is 4.5 [39].

Regarding to reducing sugar analysis (Table 4), the standard graph of glucose solution was plotted to evaluate the reducing sugar of samples before and after fermentation and then compared to each sample as shown in Fig. 3 A, B, and C; and Table 4. The sugar content of waste paper samples has been evaluated by comparing their optical density values at A 540 with the standard graph.

Table 4. Estimation of sugar using DNSA standard method.

Volume of stock standard solution (mL)	Volume of distilled water added (mL)	Amount of glucose in $\mu\text{g/mL}$	Volume of DNSA added (mL)	Keep the test tubes in boiling water bath for 10 min	dilution with D.W in ml	Absorbance at 540 nm
0.0	2	0	1.0		5.0	0.000
0.1	1.9	100				0.002
0.3	1.7	300				0.144
0.4	1.6	400				0.234
0.5	1.5	500				0.321
0.6	1.4	600				0.382
0.7	1.3	700				0.448
0.8	1.2	800				0.510
0.9	1.1	900				0.570
1.0	1.0	1000				0.716

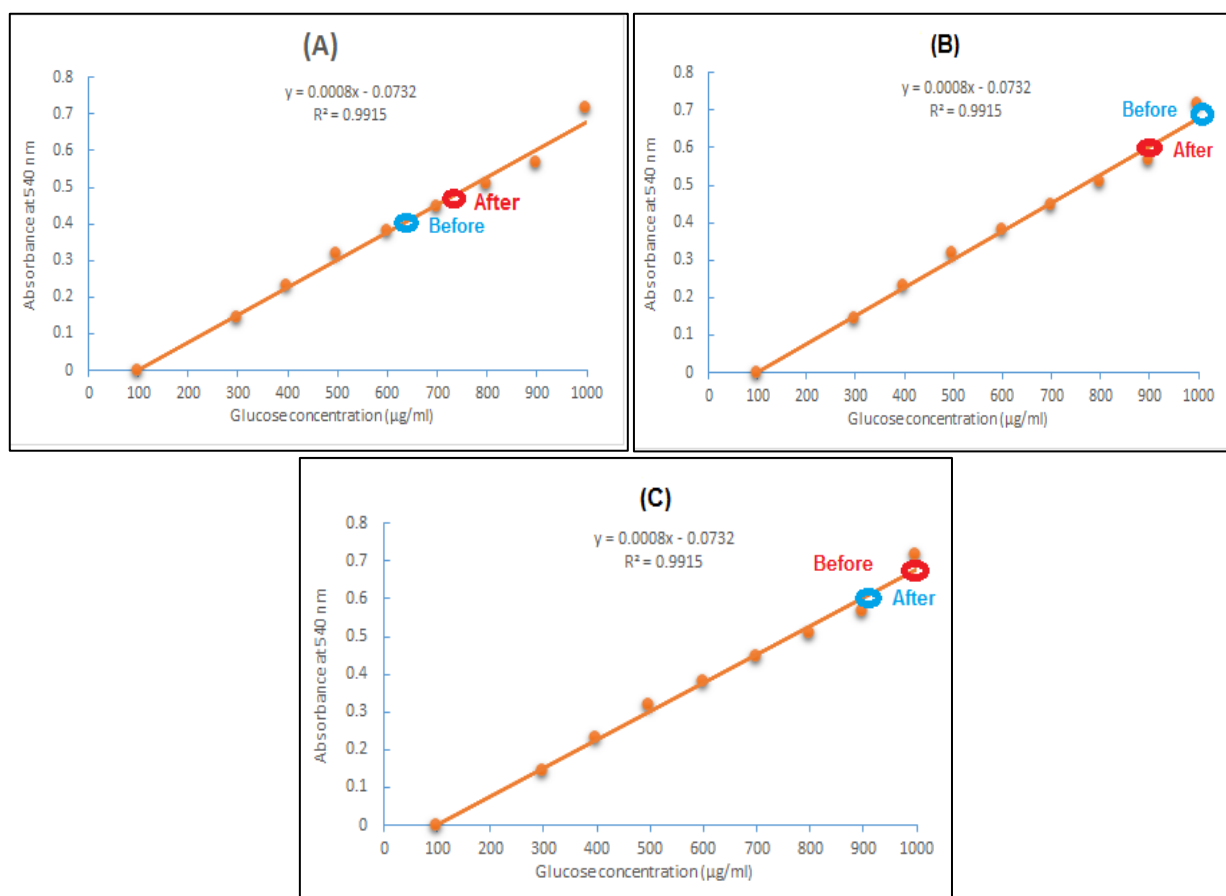
In general, the concentration of the reduced sugar in paper waste dropped dramatically (Table 5) as the fermentation process continued. The reduction in sugar level is due to the utilization of the sugar by the yeast cells to produce bioethanol [40]. The results showed that the glucose level of treated waste paper (Sample 1) eightfold declined after 3 days

of fermentation as shown in Fig. 3, whereas the glucose content of acid-treated waste papers (sample 2) dropped from 38.5 (mg/ml) at the beginning of fermentation to 4.4 (mg/ml) after 3 days. A similar trend was observed in sample 3, its glucose level reduced from 31.1 (mg/ml) to 5.5 (mg/ml) after 3 days of fermentation.

Table 5. Estimation of sugar content in office waste paper extracts before and after the fermentation process.

Vol. of paper waste fermented sample; (mL)	Vol. of distilled water added (mL)	Vol. of DNSA added (mL)	Keep the test tubes in boiling water bath for 10 min	Vol. of distilled water added (mL)	Absorbance at 540 nm	Dilution (D) (mL)	Sugar content (mg/ml)
Sample 1 ^b (1 mL)	1.0	1.0 ml		5.0 ml	0.40	45	28.1
Sample 1 ^a (1 mL)	1.0				0.45	5	3.5
Sample 2 ^b (1 mL)	1.0				0.70	35	38.5
Sample 2 ^a (1 mL)	1.0				0.60	5	4.4
Sample 3 ^b (1 mL)	1.0				0.60	35	31.1
Sample 3 ^a (1 mL)	1.0				0.70	5	5.5

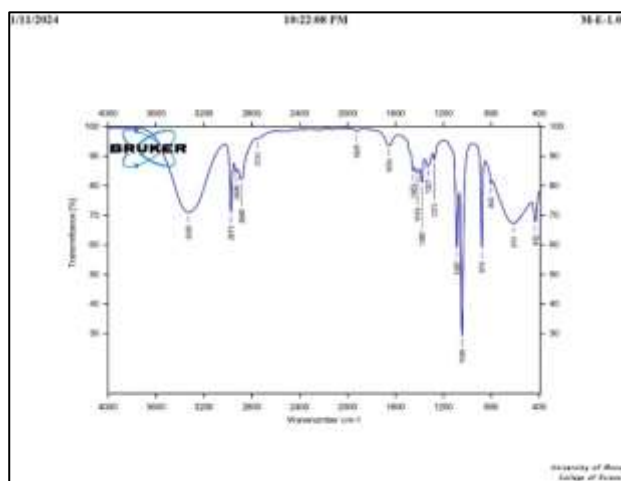
*(b): before the fermentation process, (a): after the fermentation process, and (D): dilution factor.

**Fig. 3.** Estimation of sugar content in waste paper solution before and after fermentation: (A) Sample 1. (B) Sample 2, (C) Sample 3.

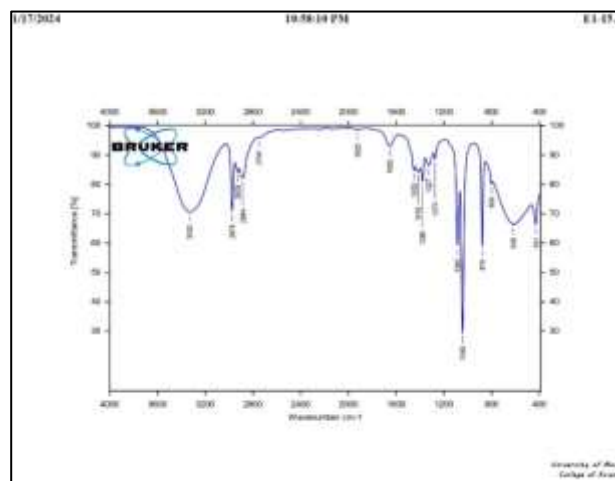
FTIR technique is a powerful tool for identifying the presence of functional groups, which present in any chemical compound. FTIR analysis of ethanol produced by different samples confirmed that the ethanol group is present. It can be seen that FTIR spectral profiles (Fig. 4-A, B, and C) of samples are similar. The results for all analyzed samples (samples 1, 2, and 3) display absorption bands typical of ethanol. As expected, a broad absorption band is assigned around 3332 cm^{-1} , which corresponds to the hydroxyl group (O-H) stretching vibration of ethanol, therefore the presence of the functional group in alcohol was verified. Other absorption bands around 2974 cm^{-1} and 2884 cm^{-1} are detected, which mainly attributed to the C-H stretching vibration. Furthermore, the sharp signal band at 1380 cm^{-1}

is also observed. This absorbance band is due to the C-OH band of bio-ethanol. Moreover, the two absorption bands appeared at 1087 and 1045 cm^{-1} , which associated with the stretching vibration of C-OH. Previous studies confirmed that the signals in the region of $2,900$ and $3,300\text{ cm}^{-1}$ in the FTIR graph of ethanol were linked to CH and OH molecule groups, respectively [41, 42]. Absorbance bands between 1045 cm^{-1} and 1380 cm^{-1} were noticed due to stretching bands of the $-\text{CH}_2$ functional group [43, 44].

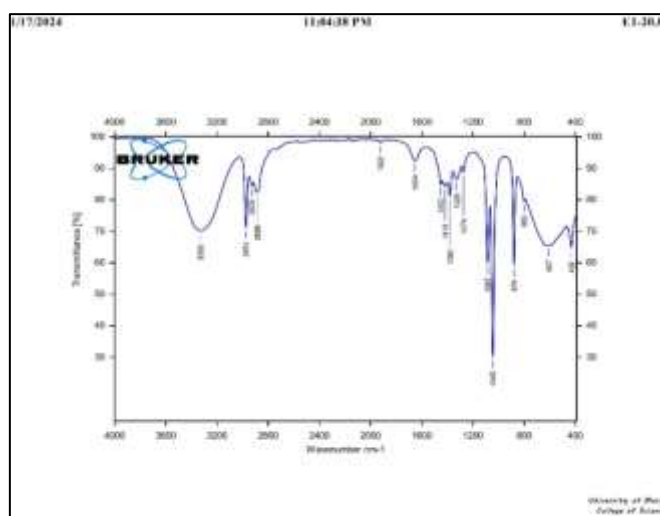
In order to obtain further helpful information about the structural molecules of pure bio-ethanol in this current study, ^1H NMR was employed to confirm the chemical compound of the pure product obtained. The chemical signals of bio-ethanol in the ^1H NMR spectrum were verified as illustrated in Fig. 5.



(a)



(b)



(c)

Fig. 4. FTIR spectrum of pure bio-ethanol, which produced from (a) sample 1, (b) sample 2, and (c) sample 3.

The ^1H NMR profile displayed three signals at different chemical shift positions, which centered at 1.09 ppm, 3.54 ppm, and 4.16 ppm. This refers to three types of proton, which were assigned to CH_3 , CH_2 , and OH , respectively. Therefore, the bio-ethanol

chemical compound ($\text{CH}_3\text{CH}_2\text{OH}$) is determined. Our results are similar to the previous findings of Hamden and her group [44] who confirmed the chemical structure of bio-ethanol using ^1H NMR technique.

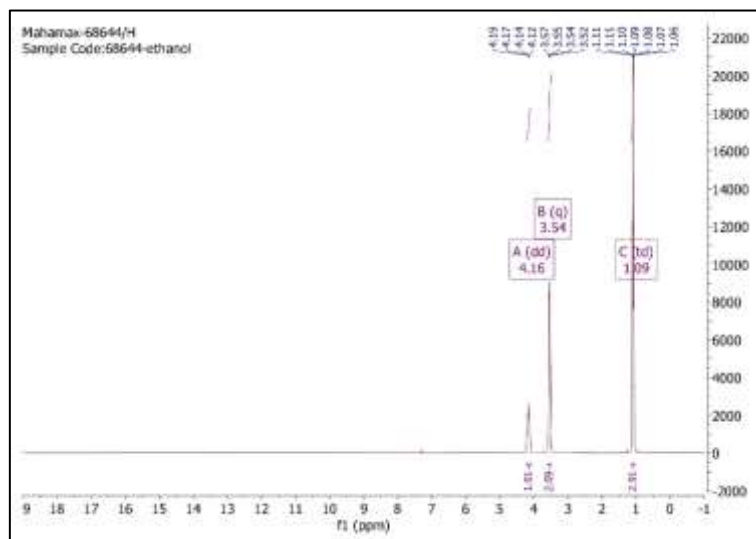


Fig. 5. The ^1H NMR Spectrum of the pure bio-ethanol obtained from office waste papers.

The current research also focused on conducting tests towards the properties and performance of ethanol-gasoline mixtures at various alcohol ratios to determine the probability of gasohol blends as an alternative fuel. Each blended fuel sample is evaluated according to ASTM in order to determine the following physico-chemical characteristics such as the density, RON, and RVP, which were listed in **Table 6**. It can be observed that densities of bio-ethanol- gasoline blends (E0, E5, E10, and E15) range from 0.727 g/cm^3 to

0.738 g/cm^3 . The densities of binary mixtures of gasohol (E5, E10, and E15) are slightly higher than the pure gasoline sample (E0) as shown in **Fig. 6**. This indicates that as volumes of bio-ethanol increase in binary mixture, densities of samples increase. This can be attributed to the higher density of bioethanol compared to the pure gasoline [45]. The following results support the findings of previous research [22], the study revealed that higher ethanol content in gasoline (E15 and E20) showed greater densities than base gasoline.

Table 6. Properties of pure gasoline and bioethanol-gasoline blends

Characteristics	Test Method (ASTM)	Bioethanol ratio in the fuel			
		E0 (0%)	E5 (5%)	E10 (10%)	E15 (15%)
Density (g/cm^3 at 15.51C)	ASTM-D4052	0.7279	0.7305	0.7344	0.7381
RVP (psia at 37 C)	ASTM-D6378	10.40	10.20	10.10	9.96
RON	ASTM-D2699	83.0	86.0	89.0	92.0
Color	yellow	yellow	yellow	yellow	yellow

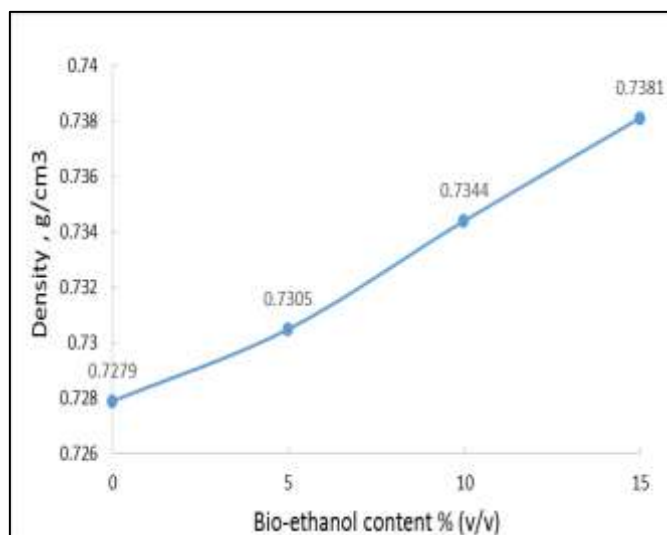


Fig. 6. Graph showing the relationship between density and bioethanol percentage in gasoline blend.

Fig. 7 represents the effect of the addition of bio-ethanol to classical gasoline on the RVP. It was found that the behavior of the binary mixture sample was significantly different from conventional gasoline despite the fact that the RVP value of bio-ethanol is much lower than

traditional gasoline. The RVP value dropped linearly with the addition of bio-ethanol to pure gasoline at various ratios, this can be attributed to the little amount water existing in the binary mixtures that may cause gasoline blend volatility change [46].

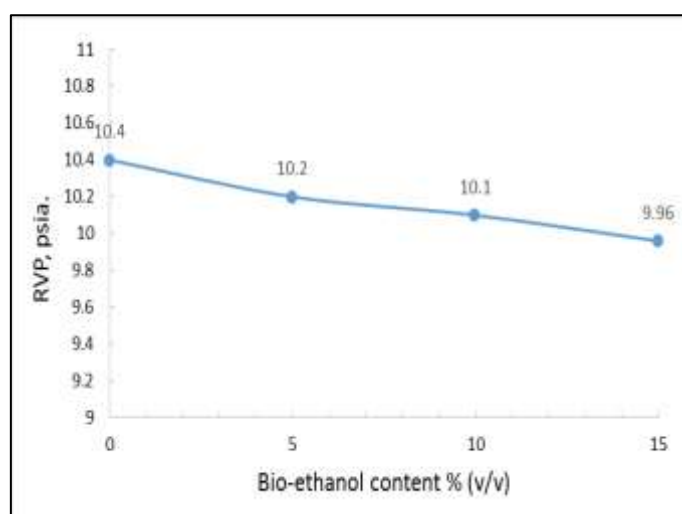


Fig. 7. Graph showing the relationship between RVP and bioethanol percentage in gasoline blend

According to Table 5, the RON values of samples varied from 83 to 92. The RON rates show a major variance in its value depending on the content % of alcohol added to the pure gasoline sample. It can be noted that the RON values for E5, E10, and E15 are higher than the conventional gasoline by 3%, 6%, and 9%, respectively. The RON value increases

gradually with the increase of ethanol content (**Fig. 8**), this is due to having a high RON value of pure bioethanol at 108 [47]. Our results coincided with previous studies that investigated the effect of binary mixtures (bio-ethanol gasoline blends) on the value of gasoline's octane number [48, 49].

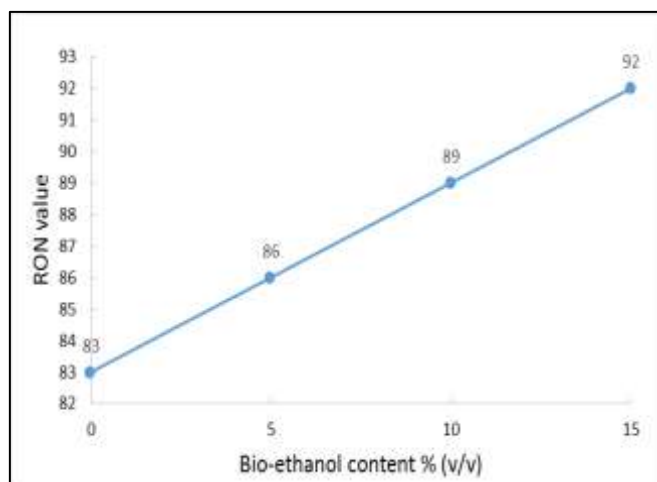


Fig. 8. Graph showing the relationship between RON and bioethanol percentage in gasoline blend

Conclusions

In this current research, office waste paper can serve as competitive raw materials for bioethanol production. Additionally, alcohol obtained can be employed as an alternative fuel to reduce the load on conventional gasoline for internal combustion engines. Regarding bioethanol production, our results displayed that relatively high concentrations of free sugars can be obtained by acid hydrolysis using 5 % sulfuric acid at a ratio of 10:1 waste office paper for 180 minutes under refluxing temperature. The yeast fermentation and purification of hydrolysate were conducted to produce high purity and yield of bioethanol at specific conditions. It can be predicted that ethanol production from office waste paper is doubtlessly the promising feedstock and an attractive business from an environmental and economic point of view. Bioethanol produced

was blended with conventional gasoline at various percentages to produce environmental gasoline (gasohol) that can be used as an alternative fuel for variable speed spark ignition up to 10 vol. % blends without engine modification. The comparative study revealed that the addition of bio-ethanol to gasoline at different ratios has affected slightly on PVP and density values of gasohol blends compared to classical gasoline. It was observed that gasoline - 15% bioethanol blend (E15) can boost the RON value by 9 more points relative to regular gasoline (E0). The binary mixture can be used as alternative fuel by the vehicle engine smoothly without any engine modification. It can be concluded that the E15 blend can properly work as a premium gasoline substitution.

Acknowledgments

We gratefully thank Mosul University for funding support of this work. The current study was carried out in the research center of the chemistry department at Education College for Pure Science. Furthermore, gasohol samples were analyzed at the petroleum quality control laboratory: at Baiji refinery in Iraq.

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