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Research Article

Feasibility Assessment of Bioethanol Production in Arid Regions using Date Palm Feedstock

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Abstract
Climate change and the need to manage diminishing fossil fuel reserves are two of the biggest challenges facing the planet. It is widely accepted that we must now reduce fossil energy consumption and increase renewable energies production. One of the important renewable energies is biomass that gradually has become more popular for its production technology in recent years. This study focuses on the innovative production of bio-ethanol as a clean and efficient fuel. In this study, the date crop, which is found in arid regions including Iran, was selected as the raw material for bioethanol production. It was shown that Iran has a high potential of producing date crops and it is, unfortunately, going to be wasted yearly. Therefore, date crops are introduced as a new feedstock to produce bio-ethanol in Iran. Hence, feasibility and economic evaluation of this ingenious method are analyzed. According to 2014 statistics, the amount of bio-ethanol production from date crops calculated, 352873.91 tons in Iran. Then, the best region for this production identified based on the amount of date produced, annually. Following that, the profitability of this project is shown through NPV calculation that obtained 203 $M. Therefore, the payback period is considered as less than one year which proves that the idea of using date crops for ethanol production is highly economical in Iran. Therefore, date palm can be considered as a desired source for bioethanol production in countries with similar conditions to Iran.
Keywords: Biomass, Clean Production, Biofuel, Renewable Energy, Date Palm

Introduction

Energy consumption is directly related to the increase in population demand and the development of societies. However, in addition to the problem of increasing energy consumption, energy resources are limited and the environment is being destroyed. Two-thirds of the world's energy needs are provided through the use of fossil fuels (Martis et al. 2020).
Regarding the limitation of fossil fuels and increasing energy consumption all over the world, it is clear-cut that the use of renewable energies and clean energy production technologies are of vital importance issues for developed countries. To many people, the most familiar forms of renewable energy are wind and solar; However, biomass (municipal and agricultural waste, animal substances and industrial waste as well) is known as one of the oldest source of renewable energies (Dhingra, 2022). Besides, it can provide more energy than other renewables by a greater production rate relative to their consumption (around eight times greater) (Balat, 2009). Also, these resources can help energy security establishment by reducing environmental consequences, such as helping to reduce greenhouse gas emissions (Daioglou et al. 2019). In

broad terms, biofuel derives from biomass that refers to plant wastes as for its nature. Biofuel includes biodiesel, biogas, and bioethanol which emerge from initial resources such as wood, agricultural product waste (sugar cane, grain...), vegetable oil, and animal fat (Chiriboga et al. 2020). Turning to details, the use of this waste for energy production process and construction of biomass power plants can be considered as sustainable development in the agricultural industry (Perea-Moreno et al. 2017).

Methane and ethyl alcohol (ethanol) are the most important products identified as fuels. Thus, researchers exploit available resources to produce ethanol as for reducing petroleum consumption and environmental pollution caused by fossil fuels (Bhan et al. 2020). Ethanol derived from biomass has the potential to replace fossil fuel as a renewable, non-toxic and environment-friendly fuel. To be precise, there are two ways to produce ethanol: synthesis, and fermentation. The second method (fermentation) is called bio-ethanol that utilizes raw materials such as date palm, corn, grain, potato and etc. Briefly put, three major classes of raw materials for ethanol production include sugar, amylaceous and lignocellulose. Regarding sugar group, ethanol emerged from date palm is the main point of this article where is commonly produced by fermentation process with Saccharomyces cerevisiae yeast under an appropriate temperature of date (Prapaspongsa et al. 2017).

The main materials of bio-ethanol production consist of sugar cane and sugar beet in Iran. On the other hand, the vast amount of produced date in this country is getting to waste annually ($\sim 85\times10^3$ ton). On a global scale, it is estimated that this amount of waste is 10 to 50% of dates produced in different countries (Taghizadeh-Alisaraei et al. 2019). To put it simply, wastes become wealth because of no initial cost of materials. Converting wastes into valuable materials has passed material status from a "carbon source" to "non-carbon" which indicates the carbon emitted to atmosphere otherwise. Also, waste can become an environmental damage if left uncontrollably (Kylili et al. 2016). The date palm trees waste contain cellulose, hemicellulose, and lignin. This resudual is usually burned directly on the farm or buried in the landfills which follows environmental hazards (Yahya et al. 2021). Despite the advantages of this energy source, there are many obstacles such as not knowing the value of this product for energy production and its optimal distribution to expand this source for energy production. It is better to do feasibility assessment as regards to realizing the best region of this valuable product. In this investigation, the clean production of bioethanol from date palm is considered by focusing the feasibility evaluations. It is wothnoting that in this research, the innovative approach of investigating bioethanol production was discussed. The innovation of this research is in combining the use of GIS with the issue of feasibility assessment of bioethanol production from date palm in Iran. Therefore, the major locations with the potential of date production are clarified using GIS method. Then, the economic calculations are considered by clarifying the net present value (NPV) parameter for a date palm production plant. To conclude, on one hand considering the significant amount of date production in Iran and on the other hand its importance in bioethanol production; In this research, using GIS and NPV calculation, the desirability of using date palm with the aim of producing bioethanol in Iran was followed.

Materials and Methods

Date Palm

The date palm (Phoenix dactylifera L.) is the type species for the genus Phoenix of the family Arecaceae (Palmaceae). Phoenix is an endemic species in tropical and subtropical areas of Asia and Africa. The date palm has been domesticated for many years in its centers of source, diversity and domestication in the Middle East and North Africa (Krueger, 2021). As it is known to all, date is considered as such agricultural crops with a high nutritious value (Younas et al. 2020) which grow in hot and tropical weather. Among major countries producing this product, Egypt, Saudi Arabia, Iran, and Algeria are the most significant. Figure 1 shows a comparison chart of date production (tons) all over the world in 2019. As it is clear that Iran is the third date producer in the world.

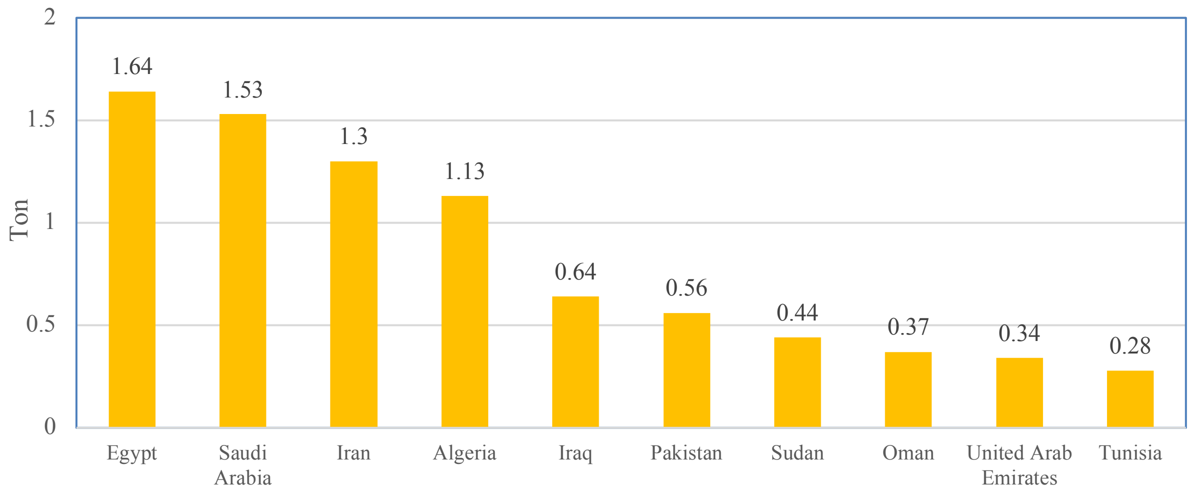

Figure 1. World's date production (tons) in 2019 (FAO, 2019)

Date is one of the most important agricultural product in Iran which is more produced in southern and tropical regions (Shabani et al. 2016). Based on statistics, date production is around 9 million tons in the world that is reported about 1.3 million tons per year in Iran as the third largest producer of this product. To elaborate on this issue, date consumption per capita in Iran is comprised 7 kg that is the average of 25 kg in southern and 1 kg in other regions. Among this production, about 10% is exported, 50% is used for domestic consumption, and 40% is going to waste in various stages of harvest (FAO, 2019). It is taken for granted that the low price of palm wastes, availability, and no need for separate space, water and energy has led these materials to be used as efficient initials for ethanol production (Gupta and Verma, 2015). Moreover, studies have shown that the use of palm waste is economically preferred (Azam and Ahmad, 2019). Due to the investigation on date residue for different sources, the formerly negative cost of materials (losing initial investments) is considered as positive income (initial materials saving). Major areas with high capacity of date in Iran are reported as Khuzestan, Hormozgan, Boushehr, Kerman, Sistan and Baluchestan, and Fars (almost southern regions). Due to the poor quality of date produced in the country, a high share of products are wasted.

Ethanol

Ethanol or ethyl alcohol (C_2H_5OH) is a clear colorless liquid. It is one of the substances that are considered as an alternative to fossil fuels. Taking into account that 35% Oxygen exists in ethanol component, it is found as a clean source. In addition, it can considerably reduce the amount of greenhouse gasses which are emitted by combustion process (Tavares et al. 2014). Also, ethanol can be produced by other clean sources such as cellulosic and other wastes existed naturally.

Further, economic matters become significant in the case of waste's low price used as initial components for ethanol production (Bunphan et al. 2015). Figure 2 shows global ethanol production by country/region and year. Global production peaked in 2015 after a dip in 2012 and 2013. The United States is the world's largest producer of ethanol, having produced nearly 15 billion gallons in 2015 alone. Together, the U.S. and Brazil produce 85% of the world's ethanol (EIA, 2015).

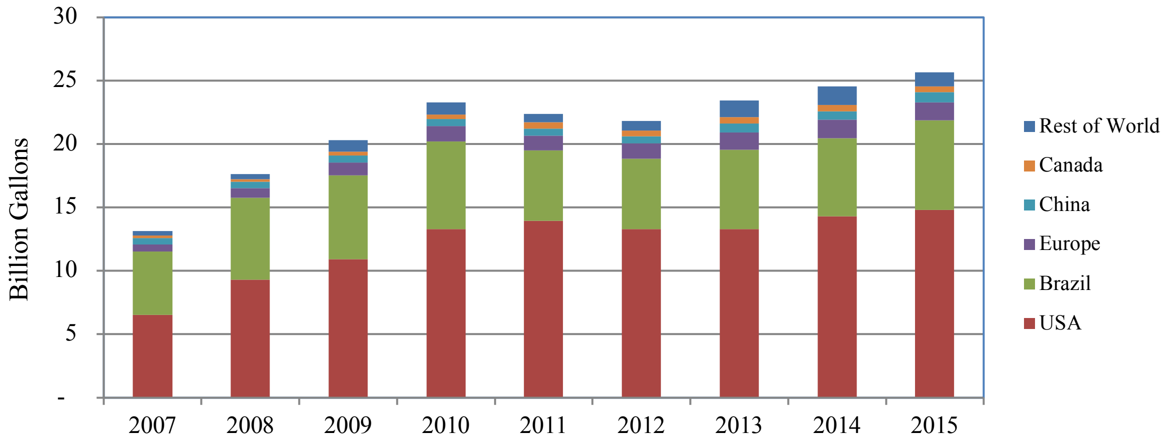

Figure 2. Global ethanol production by country/region, from 2007 to 2015 (EIA, 2015)

Bioethanol

Bioethanol is an available, clean fuel for combustion engines that can be produced from an array of different biomass feedstock's and conversion technologies. Precisely, food based and non-food materials are considered as the initial substances (Figure3). Sugar based crops are kind of substantial in the field of bioethanol production. It is needless to say that only the wasted crop, which is defined as crop lost in distribution, is considered as a feedstock (Janani et al. 2013). These crops are grown specifically for energy use and include corn, maize and wheat crops, waste straw, sorghum plants and etc. There is also ongoing research and development into the use of municipal solid wastes to produce ethanol fuel. Cellulose is a further possible source but its availability is poorly documented (Vohra et al. 2014). The feedstock used for ethanol fuel production is mainly sugarcane in tropical areas such as India, Brazil, and Colombia, while it is dominantly corn in other areas such as the United States, the European Union, and China (Cheng and Timilsina, 2011). According to statistics, sugar crops account for approximately 40% of the total bioethanol produced and nearly 60% corresponding to starch crops (Mussatto et al. 2010). The importance of sugar crops is that they can directly convert to ethanol by microorganisms. On the other hand, starch and cellulose should first hydrolyze to sugar and eventually convert to ethanol by fermentation (Jambo et al. 2016). Among these types of resources, there is no document depicts an investigation of using date palm crops and specially wastes as bio-ethanol production in one of the most important origins of date production (Iran) which can make this study as an innovative.

Feasibility Analyses

GIS Methodology

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map. This enables people to more easily see, analyze, and understand patterns and relationships. Once all of the desired data have been entered into a GIS system, they can be combined to produce a wide variety of individual maps, depending on which data layers are included. GIS maps can be used to show information about number and density .

There are a number of documents illustrate the use of GIS. For instance, in 2021, potential facility locations for ethanol bio-refinery sites based on agricultural residues analyzed by using GIS methodology and the best locations in aspect of biomass availability identified (Zheng et al. 2021).

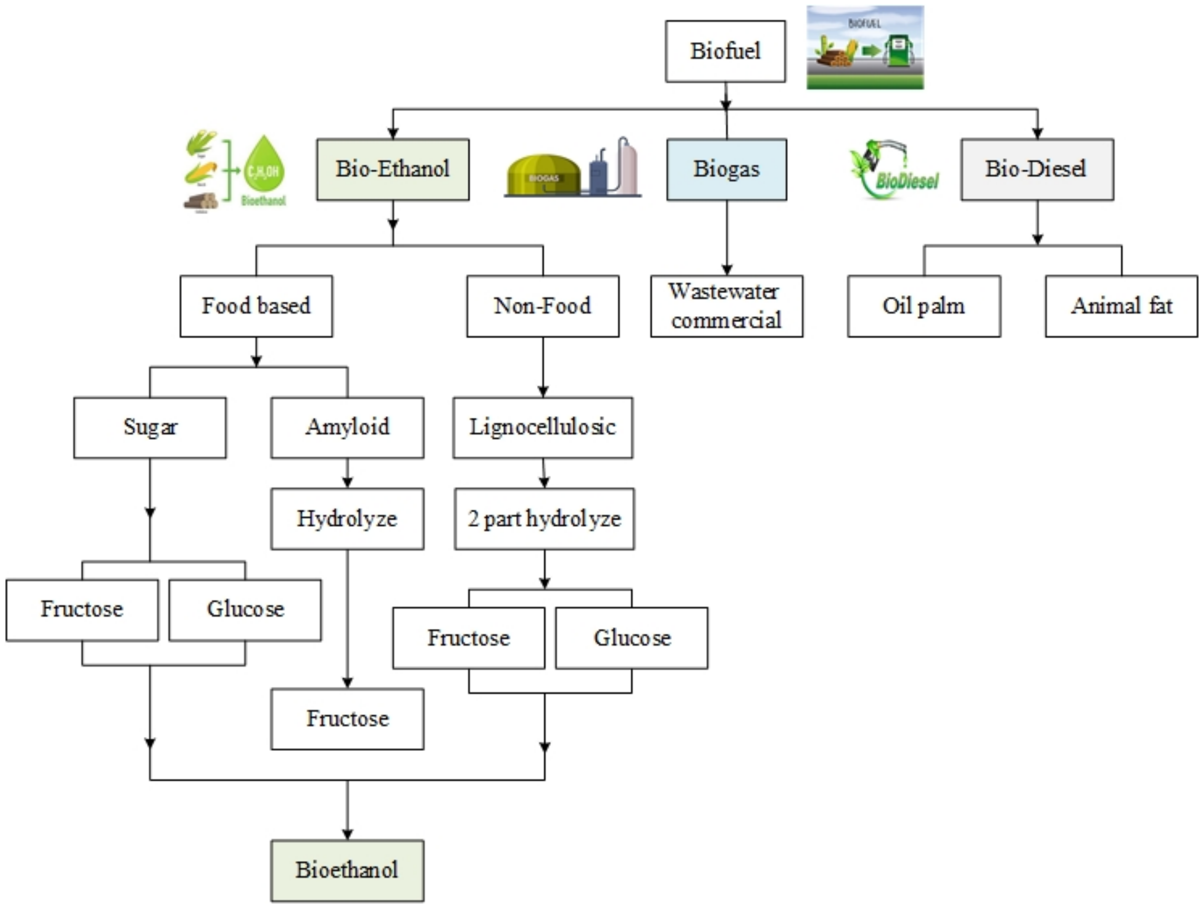

Figure 3. Different biofuels structure and bioethanol production process.

Another study that was conducted with the aim of assessing feasibility of renewable energy resources for tea plantation and industry showed up to 83% of the heat energy required in the tea industry can be provided from the energy obtained from tea waste (Kumar et al. 2021). In addition, a GIS-based methodology for the assessment of sustainable crop residue potentials presented. Results showed the best region for biomass resources in Europe (Haase et al. 2016). In this study, all the areas where dates are harvested were selected for investigation (Table1). Then, the amount of bio-ethanol production resulted by using mathematic calculation. Furthermore, the best locations of date palm and bio-ethanol are mentioned in Iran map using GIS software. At last, economic analysis is considered through NPV calculation.

Results

Date palm potential in Iran

According to Table 1, date palm production, performance, and area in each province are observed. Figure 4 is shown the distribution of date palm production (tons) in Iran by using GIS method. As a result, southern area of the country are the most feasible regions in order to grow date palm.

Bio-ethanol potential in Iran

According to researchers, 40% of date crops are wasted in Iran annually since they have been wiped out in stocks. To be exact, 21% is wasted before getting access to the consumers. Another significant resource is a low-grade date which is considered waste per year. Table 2 is shown different types of date, their prices in each grade, and their production rate in Iran. Thus, it is of vital important to use these waste for well-improving economy of the agrarian industry. One of the most enriching uses of these crops is industrial production of bioethanol taking into account obtaining efficient results.

Table 1. Date palm production, performance, and area for each province of Iran in 2014 (Ministry of Agriculture, 2015)

Province	Area (hectare)	Date Production (ton)	Performance (kg in hectare)
Esfahan	196	128	653
Ilam	55	118	2146
Boushehr	29729.6	143450	5006
south Kerman	28037	181034	6457
South Khorasan	1265	5327	4211
Khuzestan	25785	143550	5567
Semnan	53	280	5283
Sistan and Baluchestan	34292.5	172931.5	6798
Fars	25890	132279	5630
Kerman	24314.9	109600	4508
Kermanshah	212.3	133	627
Kohgiluyeh and Boyer-Ahmad (KBA)	47.5	155	3263
Hormozgan	27230.3	118055	4708
Yazd	2006	6965	3472
Total	199114.1	1014005.5	58330

Figure 4. Distribution of date palm production (tons) in Iran.

Table 2. Different types of date, their prices in each grade, and their production rate in Iran (Ministry of Agriculture, 2015)

Name	First grade($/Kg)	Second grade($/Kg)	Production rate (%)
Mazafati	1.40	1.18	73.24
Kabkab	0.96	0.81	13.95
Astamaran	1.84	1.5	11.5
Rabbi	1.68	1.43	6.6
Shahani	1.46	1.09	4.93
Piarum	5.59	4.37	0.8
Dayri	1.09	0.78	0.41
Barhi	1.03	0.84	0.41
Others	0.46	0.28	41.07

Regarding Table 2, it is clear that about 41% of total date production is related to low-grade ones that can be used as bioethanol feedstock as well. Based on researches the existed sugar in different date is about 60% in average.
According to assays, there are two scenarios for bio-ethanol production. First, one is included of stock waste (8.4% of total date production as mentioned before). The second scenario is represented the low-grade date that is considered 41% based on table 2. Equation bellow is shown bio-ethanol production base upon two discussed scenarios.

$$Bio\ ethanol(ton) = [(date\ production * 0.084) + (date\ production * 0.41)] * 0.6 \quad (1)$$

Stock waste — Low-grade — % Sugar

Assuming two discussed scenarios, bio-ethanol production in each province is calculated (Table3). Due to this table, the amount of total bio-ethanol production in Iran is 300551.23 tons. Moreover, potential analyses are conducted using GIS methodology. Therefore, identified location is shown on a map illustrating bio-ethanol production (Figure 5).

Figure 5. Bio-ethanol production map of Iran (Taghizadeh-Alisaraei et al, 2019)

Table 3. Bio-ethanol production in each province of Iran based on two scenarios.

Province	Area (hectare)	Product (ton)	Stock waste(ton)	Low grade(ton)	Bioethanol(ton)
Esfahan	196	128	10.75	52.48	37.94
Ilam	55	118	9.912	48.38	34.97
Boushehr	29729.6	143450	12049.8	58814.5	42518.58
South Kerman	28037	181034	15206.85	74223.94	53658.48
South Khorasan	1265	5327	447.46	2184.07	1578.92
Khuzestan	25785	143550	12058.2	58855.5	42548.22
Semnan	53	280	23.52	114.8	83
Sistan and Baluchestan	34292.5	172931.5	14526.24	70901.91	51256.9
Fars	25890	132279	11111.43	54234.39	39207.49
Kerman	24314.9	109600	9206.4	44936	32485.44
Kermanshah	212.3	133	11.172	54.53	39.42
Kohgiluyeh and Boyer-Ahmad (KBA)	47.5	155	13.02	63.55	45.94
Hormozgan	27230.3	118055	9916.62	48402.55	34991.50
Yazd	2006	6965	585.06	2855.65	2064.43
Total	199114.1	1014005.5	85176.46	415742.25	300551.23

Economic evaluation

The economic evaluation is obtained using equation 2. In order to analyze the profitability of this project, net present value (NPV) is calculated based on financial parameters as follows (Yassin and Derar 2014).

$$NPV = \sum_{k=1}^{5} \frac{Sk}{(! + i)k} - FC \quad (2)$$

where i is the discount rate, S is annual cash flow which is considered yearly and FC is the total fixed capital costs. Alternative fuels data center reported ethanol price as 1.84 $/gallon. Considering ethanol density 789 kg/m³ at room temperature, annual price for total ethanol production is calculated 185159672.8 $. So, due to the amount of low-grade date which is sold (116407831.4$), annual cash flow is obtained 68751841.4$. Besides, fixed costs represented the equipment used for industrial production process of ethanol (Figure 6). Also, table 4 shows equipment price and economic values for bioethanol production plant. Thus total fixed capital cost is calculated 1705000$ in annum.

The process contains three main components: pretreatment, fermentation, and purification. The first tank is used for pretreatment in order to reduce crystallinity and increase the porosity of feedstock. This level used acid and alkali. The second tank is originally the bioreactor which is proceeded using yeast (saccharomyces cerevisiae) as for bioethanol conversion. Then, bioethanol is purified in two distillation column and one adsorption unit for dehydration. Finally, purified ethanol is obtained and stored in the storage tank. Also, waste water is reached to a storage tank for pretreatment process (Do et al. 2015).

On the basis of Iranian central bank, the discount rate is observed 20% in average for recent five years. Assuming the same cash flow is observed as 2014 which bioethanol production is calculated due to this year. Regarding equation 2, NPV is calculated about 203 $M. This positive NPV is represented high economic possibility on this project. Moreover, the payback period on this project is less than one year.

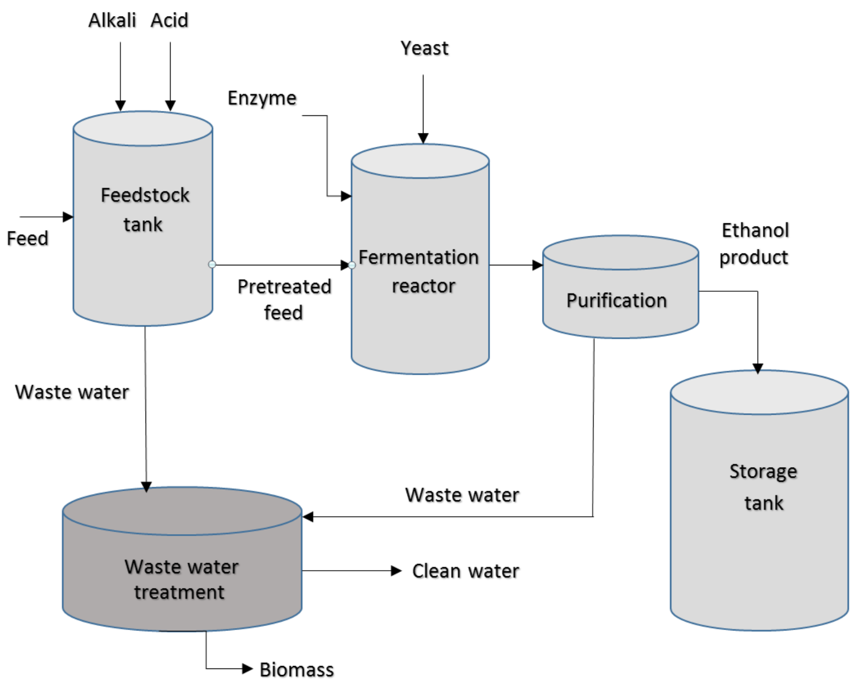

Figure 6. The equipment used for industrial production process of ethanol (Do et al. 2015)

Table 4. Equipment and economic values for ethanol production plant (Zheng et al. 2021)

Equipment	Amount	Cost($)
Storage tank	3	100000
Pretreatment storage tank	1	100000
Bioreactor- stainless steel	1	150000
Distillation column	2	150000
Adsorption unit	1	100000
Pump-Centrifuge	3	100000
Valve	15	150000
Labor	Per year	200000
Total	-	1050000
Economic value		
Land	-	500000
Fixed costs	-	1550000
Transportation	10% fixed costs (Harmsen et al. 2018)	155000
Total Fixed capital costs	-	1705000

Conclusions

Due to the many disadvantages of fossil fuels, the need to new sources has become more prominent in recent years. Unlike fossil fuels, biofuels are kind of renewable resources which can be produced from an array of different simple feedstock in nature. A new generation of biofuels is considered as trash turning into treasure. As a matter of fact, agricultural crops are going to be a proper feedstock for bioethanol production where date palm is a state of the art among these raw materials. Most importantly, Iran is the third producer in case of date. For this reason, date distribution is analyzed in this country and the best region is observed as well. Then, bioethanol production is calculated 300551.2 tons in 2014, using two feedstock scenarios: low-grade date and stock waste. Regarding financial analyses, economic evaluations carried out in this project. Hence, NPV is obtained 203 $M and the payback period is considered less than one year. So, using date palm fruit as a new raw material is highly recommended in Iran's industry. In various studies (Ahmad et al. 2021; Afolabi and Ola, 2022), similar to the results of this research, it was emphasized that date palm can be used as a desirable raw material for the production of bioenergy and has a good efficiency in this case. Worth to mention based on the results of this research, date palm in Iran can be used as a very suitable raw material for the production of bioethanol. According to the obtained results, the provinces located in the south and southeast of Iran have a large capacity to produce bioethanol from date palm. Therefore, it is obvious that countries with the similar climatic conditions of Iran (especially MENA countries) can invest significantly in this method of bioethanol production.

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