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Conversion of residues from agro-food industry into bioethanol in Iran: An under-valued biofuel additive to phase out MTBE in gasoline

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ABSTRACT

It is obvious that Iran agricultural industry, unlike Brazil and USA, cannot afford to provide conventional biomass, *i.e.* sugary or starchy biomass for bioethanol production, mainly due to climatic and geographic conditions. With some exception of date (fruit), first-generation ethanol production triggers food *vs.* fuel debates in Iran and put nation to hunger. Agricultural products including apple, barley, carrot, corn, grape, orange, potato, rice, sugar beet, sugarcane, and wheat are consumed domestically, exported, or even lost because of poor harvesting and processing conditions such as transportation or packaging. These products may alone generate 21.56 million ton per annum green wastes upon processing in the food industry. Every year about 5.4 billion liters of bioethanol can be produced by establishing second-generation ethanol plants next to the food processing sectors. Seventy-seven-percent of this amount of bioethanol can easily support 5% ethanol (E5) policy to phase out the consumption of 4.2 billion liters methyl tert-butyl ether (MTBE) for raising the octane number of gasoline in the country. If more comprehensive policy is adopted, larger quantities of lignocellulosic feedstocks can be gathered from agro as well as forestry practices. Second-generation bioethanol technology can help Iran to tackle air pollution in its big cities and to address the adverse effects of MTBE on its populations and ecosystem. The other advantages are improvement of fuel security, mitigation of climate change, and development of economy. The motivation can be created through passing a framework policy to cut fossil fuel subsidies, to mandate bioethanol blends in gasoline, and to impose carbon taxes. Development of coherent socially and environmentally relevant strategies and facilitation of investment in bioethanol industry are also necessary.

1. Introduction

Air pollution is considered as a cause of death, and while indoor air pollution can be reduced in some extent using a number of technologies, the control of outdoor pollution is difficult. It is predicted that the annual deaths associated with outdoor pollution will rise from 3 million to 4.5 million by 2020 [1]. This number of premature deaths is accounted for US$225 billion and US$5.11

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Abbreviation

List of Abbreviations with their definitions

AA	Acetic Acid
CBP	Consolidated Bioprocessing
DMC	Direct Microbial Conversion
E5	5% Ethanol in 95% Gasoline
FA	Formic Acid
MTBE	Methyl Tert-Butyl Ether
AFEX	Nh_3 Fiber/Freeze Explosion
PAA	Peracetic Acid
PFA	Performic Acid
PEG	Poly(Ethylene Glycol)
SHF	Separate Hydrolysis and Fermentation
SSCF	Simultaneous Saccharification and Co-Fermentation
SSF	Simultaneous Saccharification and Fermentation
TEL	Tetraethyllead

List of chemical formulas and symbols with their chemical names

CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
Ca(OH)2	Calcium Hydroxide
HCl	Hydrochloric Acid
HNO3	Nitric Acid
H2O	Water
H3PO4	Phosphoric Acid
H2SO4	Sulfuric Acid
KOH	Potassium Hydroxide
NaOH	Sodium Hydroxide
NH3	Ammonia
NH4OH	Ammonium Hydroxide
NOX	Nitrogen Oxides
N2O	Nitrous Oxide
O2	Oxygen Gas
Pb	Lead
SO2	Sulfur Dioxide
SO3	Sulfur Trioxide

trillion lost labor income and welfare, respectively [2]. Borders cannot constrain air pollution emitted by industrial facilities, power plants, and vehicles, therefore, a coordinated implementation of proven remedies across organization and nations is required. The Paris climate summit is the most recent movement that tries to unify countries to mitigate air pollution for saving life on the earth. A sustainable and effective solution is production of clean forms of energy [3–7]. In oil-rich countries like Iran, owing to low price of crude oil, the development of renewable sources of energy is trivial (Fig. 1).

This lag in sustainable energy development has exposed Iran to intense air pollution (Table 1), particularly, in its big cities. In 2015, the shares of transport sector in total emissions of carbon monoxide (CO), carbon dioxide (CO_2), nitrous oxide (N_2O), nitrogen oxide (NO_x), sulfur dioxide (SO_2), and sulfur trioxide (SO_3) in Iran were close to 97%, 23%, 52%, 48% 26%, and 31%, respectively. Additionally, transportation resulted in generation of 78% of the total particulate matters emitted in Iran in the same year [8].

Currently, more than 10 million people reside in megacity Tehran, where 85% of the air pollution were emitted from vehicles in 2013 [9]. Therefore, a gradual replacement of the fossil liquid

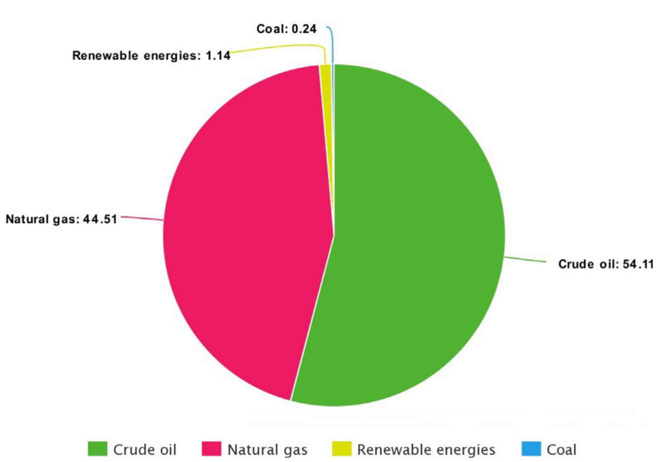

Fig. 1. Energy production in Iran. Source: Ref. [8].

fuels with biofuels like bioethanol may help the country with a significant reduction of air pollutants in its big cities [10,11]. The application of ethanol as fuel is not new and indeed it has helped the human when there were not enough fuels, for examples during World Wars and oil crises (Fig. 2).

However, the condition during war is different than peace era from economic point of view. With various ups and downs, ethanol has been finally approved as biofuel of choice and currently accounts for up to 95% of global biofuel production with capability to replace 32% of the global gasoline consumption (353 billion liters) [12]. Despite this significant potential, Iran has not yet exploited any advantage of bioethanol application as blends. The only program in the substitution of gasoline with E5 was remained unfruitful by shifting favors toward methanol, which itself is continuously postponed. In addition to the generation of higher contents of pollutants by gasoline than green fuels, it tends to autoignite in high-compression internal combustion engines, causing engine knocking. To address this issue, octane enhancer compounds are added to gasoline to slow the burning of the gasoline and reduce knocking. For more than 80 years, lead (Pb) was used in form of tetraethyllead (TEL) for this purpose. It was reported that this heavy metal can be accumulated in human body and causes adverse health effects, particularly on children, as well as other ecological issues [13]. This exploration led to global elimination of Pb in gasoline, leaving only a small numbers of countries still using it. In Iran, leaded gasoline containing 0.19 g/L Pb, was replaced with unleaded one by January 2000 that removed eight tons of Pb from gasoline in the following year. Currently, Iran mixes MTBE in gasoline (1:9 v/v) to improve gasoline octane number. In this communication, biomass security and its preparation for the microbial fermentation of ethanol in Iran for the possible application of ethanol blends in gasoline E5 (phasing-out of MTBE) or E10 are investigated.

2. Fermentation substrates

One of the most important problems with bioethanol fermentation is the security of feedstock, which is highly fluctuant not only from season to season but also from region to region. Therefore, climatic- and geographic-related stresses make the price of the feedstock highly volatile, which in turn affect the production costs