Biobutanol as An Alternative Energy Source

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Key Insights/Abstract

Energy demand is increasing day by day in Pakistan, due to rapid increase in population, industrialization,urbanization and technological spread for human comfort. But the availability of energy becomes a challenge due todepletion of limited reserves of fossil fuels. As a result of high dependency on imported fuels that effects foreign exchange reserves of the country and pushes its current account under pressure. It contributes major portion of imports while increases the gap between imports and exports. Thus, the country rolls under energy insecurity. On the other hand, adverse climatic effects become a momentous issue due to emission of greenhouse gases (GHG's) from conventional fossils. While those emissions ultimately resulting global warming and health issues. The only way to mitigate and resist those issues is to adopt alternative and renewable energy source to meet the energy demand. Biobutanol is under the domain of bioenergy. It can be an alternative source of energy for our transportation sector. It is an attractive fuel because of its properties such as energy density, autoignition temperature and octane rating etc. It can be a sustainable renewable fuel to use in internal combustion engine when produce from conventional feedstock in Pakistan. Even it can also be a good blending and replacement option for conventional internal combustion engines without engine modification. Current study focuses biobutanol as an alternative energy source in Pakistan.

Research Context

The demand of energy is increasing rapidly in Pakistan [1]. Reasons for the increasing trend includes population growth, industrialization, urbanization and technological spread for human comfort [2]. The country has limited reserves of fossil fuels and thus availability become a challenge [3]. From the increasing demand of fossil fuels, the country faces economic instability. As a result of high dependency on imported fuels to meet the energy demand that effects foreign exchange reserves of the country and pushes its current account under pressure. Petroleum group import bill having a share of 20.15% of total imports [4]. On the other hand, the country is facing adverse climatic effects along with the world due to those fossil fuels [5]. It became a momentous issue globally from the emission of greenhouse gases (GHG's) from conventional fossils by using them in transportation, power generation and other sectors. While those emissions ultimately resulting global warming and health issues. Global Health Observatory of World Health Organization estimates, about 200 deaths per 100000 population are attributable to environmental factors in Pakistan. The only way to mitigate and resist those issues is to adopt alternative and clean energy like biofuels [6]. It does not emit GHG's to the atmosphere and can be produce from conventional biomass of the country.

Pakistan is a agricultural country and produces a number of crops. Sugarcane, Rice, Maize and Wheat production is continuously increasing [7]. One of the major sectors of consideration for biofuels is transportation; on this sector biofuels are rapidly proved themselves to be an impressive option. Therefore, it is anticipated that out of all the renewable resources, biofuels are potential source of energy that can serve immensely to the current energy crises [8]. The current focus is also on one such fuel which is biobutanol. Biobutanol is a bioalcohol which produces from fermentation

of carbohydrates. It has competitive properties with other biofuels and petroleum fuels especially when we look towards internal combustion (IC) engine. It is a more valuable fuel because of its high energy density and renewable resource. The study also focusses on all such perimeters including feedstock, production routes etc.

Research Design

Feedstock is the key perimeter to produce any biofuel [9]. The selection of feedstock depends upon the conventional availability of a biomass in a country and its annual growth rate variations. Carbohydrate is the main source of production of any bioalcohol so that more carbohydrate content present in a feedstock more will be the yield of bioalcohol. Sugar and starch based feedstocks are the direct source of biobutanol production and are feasible in terms of availability in Pakistan. But the production from those feedstocks which use to fulfil the needs of food is a problem and this kind of feedstocks also requires large amount of water [10]. Despite of the problem of lignocellulosic feedstocks, production of 2nd generation biobutanol from waste feedstocks as a substrate is a very good option. There are several routes from which biobutanol can be produce. Biobutanol is producing from microbial fermentation (ABE fermentation or Clostridial fermentation) on commercial scale but in this process 60% of the total production cost takes by substrate. As compared to chemical synthesis, biobutanol production from biological process is quite Discussion Paper: Biobutanol as an alternative energy source Syed Wamiq Ali Jafri and Rohaan Kidwai 2 ecofriendly [11]. To produce biobutanol there are various steps we have to follow which includes saccharification, fermentation and separation as shown in Figure-1. Saccharification takes place at the beginning with the help of either acid or enzyme that converts the carbohydrate present in the substrate into fermentable sugar. The extracted sugars then transform into biobutanol from bacteria or yeast in fermentation. Biobutanol thus produce from the process is in different proportional depending upon carbohydrate profile of the substrate and type of bacteria used for fermentation.

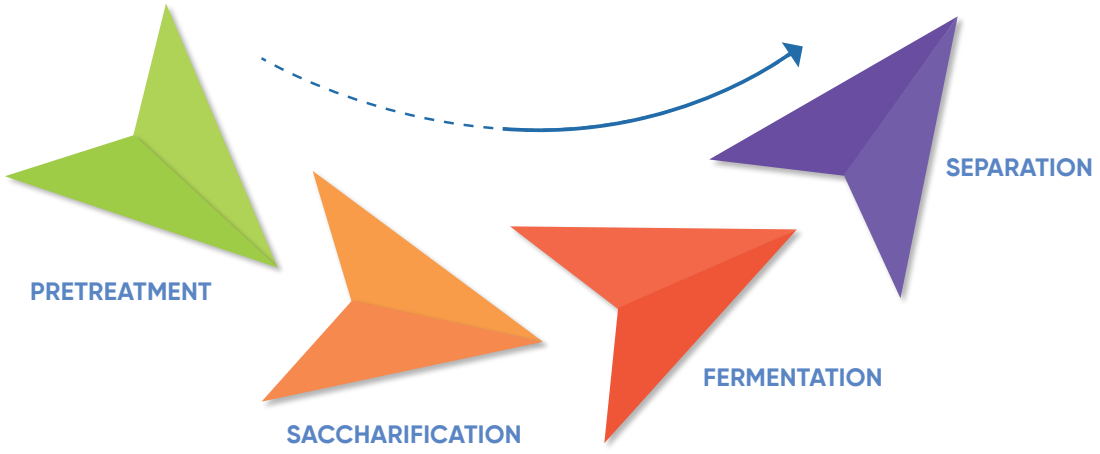

Figure 1: Steps for Biobutanol Production

Now recovery of biobutanol can be perform through different technologies such as thermal, mechanical or electrolytical process etc. Several production routes are summarized in Figure-2.

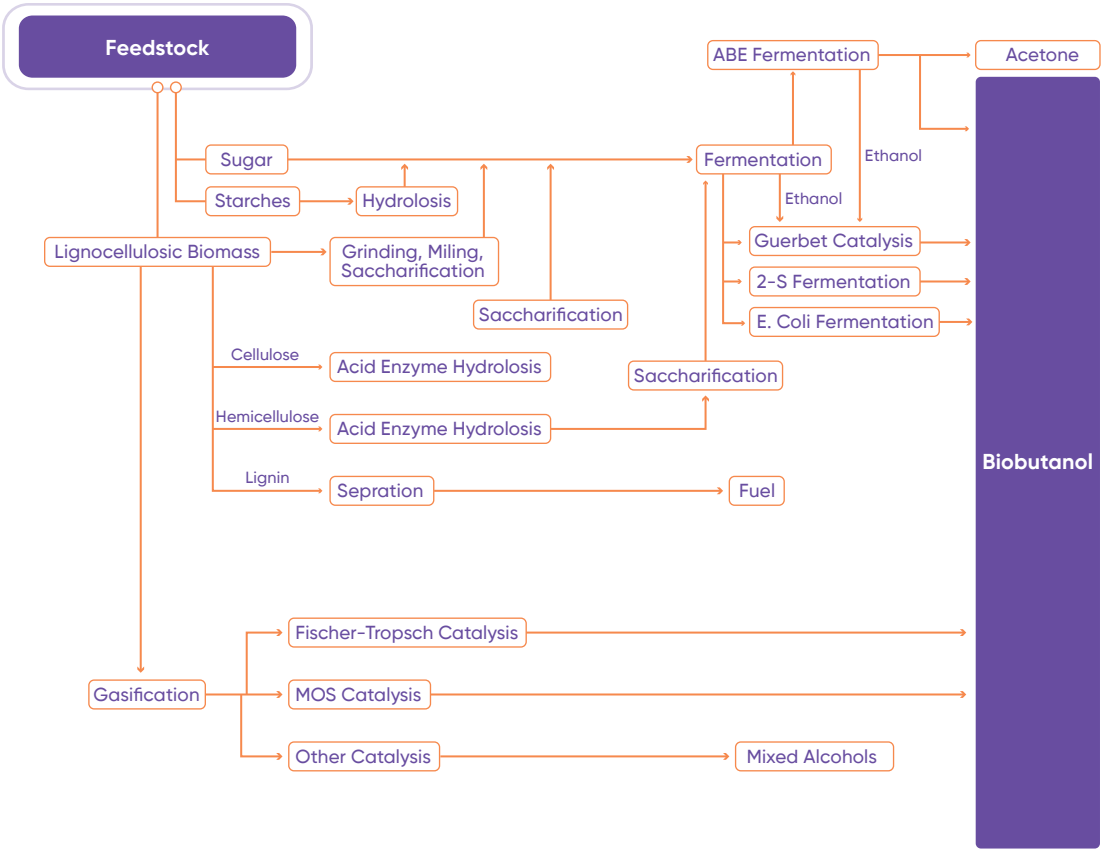

Figure 2: Production Routes

Key Findings and Discussion

Numerous starch and lignocellulose-based wastes of corn, rice sugarcane and wheat, have been used as feedstock for the production of butanol. Large amount of solid and liquid wastes have been produced during agriculture activities. Various waste feedstock for biobutanol production along with pretreatment and microorganism are listed in Table-1. Corncob contains starch and used as substrate for the production of biobutanol. Fermentation was performed, using the Clostridium acetobutylicum strain at 37'C in a 7 L anaerobic fermenter. Another corn-based lignocellulosic residue has been evaluated for biobutanol production by a different strain. Therefore, low concentration acid pretreatment has been carried out to increase sugar formation and reduce inhibitor.

Another lignocellulosic rice straw waste was tested with the new process. Rice straw containing cellulose and hemicellulose was converted into biobutanol. Moreover, the enzyme hydrolysis was carried out as pretreatment. Ultimately, this treatment process will damage the lignin structure and build up more lose cellulose and hemicellulose. This new integration process results in an efficient

method of producing biobutanol from rice straw, which results in a higher yield and production rate. Other lignocellulosic waste of wheat bran and straw was used with acid and biological pretreatments respectively. Reasonable amount of recovery achieved with Clostridium species.

Feedstock	Pretreatment	Microorganism	Fermentation	Butanol Recovery	Reference
Corncob Residue hydrolysate	Enzymatic hydrolysis	C. beijerinckii NCIMB 8052	96 h batch fermentation at 37 'C	5.6 g/L	12
Corn stover	Steam explosion, Alkaline	C. acetobutylicum ATCC 824	Batch fermentation for 72 h at 37 'C	10.07 g/L	13
Corn stover hydrolysate	Alkaline, Ionic liquid, Enzymatic hydrolysis	C. saccharobutylicum DSM 13,864	68 h batch fermentation at 37 'C	7.4 g/L	14
Rice bran	Acid	C. saccharoperbutyl-acetonicum N1–4	128 h batch fermentation	6.8 g/L	15
Rice straw	Alkaline, Enzymatic hydrolysis	C. acetobutylicum NRRL B-591	172 h ABE fermentation at 37 'C	1.4 g/L	16
Sugarcane bagasse	Alkaline	Mixed culture of Clostridial Species	Fermentation	2.29 g/L	17
Wheat bran	Acid	C. beijerinckii ATCC 55,025	72 h batch fermentation	8.8 g/L	18
Wheat straw	Biological	Coculture of C. beijerinckii 10,132 and C.cellulovorans 35,296	Batch fermentation at 37 'C	14.2 g/L	19

Table 1: Conventional Feedstock

Biobutanol is a bio-based alcohol having molecular formula C4H9OH. It is a colorless liquid having banana like odour with lower volatility [20]. In short, biobutanol is a better solution to exclude the distress of other fuels. In comparison with other fuels biobutanol showed sound properties and the facts demand persistently to promote this renewable biofuel as shown in Table-2. In the prevailing fuel infrastructure biobutanol can be tackle conventionally in existing engines or with built-in intrastate. And the property analysis shows reasonable outcomes. These analyses also help in further research on biobutanol and in design perimeters of engine. These are the characteristics of biobutanol which makes it an outstanding biofuel because of the resemblance of biobutanol with other fuels.

Properties	Diesel	Gasoline	Methanol	Ethanol	Butanol
Density (kg/L)	0.82 –0.86	0.72 –0.79	0.796	0.785 – 0.79	0.808 – 0.81
Vapor Specific Gravity	5.5	3.5	–	1.6	2.6
Viscosity (mm2/s)	1.9 –4.1	0.4 –0.8	0.59	1.08	2.63
Boiling Point ('C)	180 –370	30 –210	65	78	118
LCV (MJ/kg)	42.6	43.2	20	26.9	33.2
Autoignition Temperature ('C)	220	300	470	410	364
Flash Point ('C)	64 –85	–43	12	9	1.4– 11.2
Flammability Limit (%Vol.)	0.6 –7.6	0.9 –7.9	6.0 –36.5	3.3 – 19	1.4– 11.2
Octane No.	20 –30	80 –100	111	108	96
Cetane No.	40 –52	0 –10	3	7– 10	17 – 25
Reid Vapor Pressure (kPa)	› 3	62	32	12	2.3
Oxygen Con-tent (%wt.)	–	› 2.7	50	34.7– 34.8	21.6

Table 2: Comparison of Properties

Policy Recommendations

- Challenges associated with biobutanol production need to be overcome by ensuring availability of sustainable feedstock and increasing yield by evolution of fermentation process.
- In addition, substantial advances in the use of waste as biomass will be achieved through research highlighting economic feasibility. Furthermore, huge attention needs to be given to the efficaciouseness of waste to energy technologies.
- Development of the sector need to be made by encouraging foreign direct investment and incentivization.
- In the automobile sector, developing engine design and configuration of hybrid mode of both gasoline and diesel along with biobutanol will help to accomplish the latest trend in accordance with the future emission standards.

- A detoxification process is required that is integrated along with pretreatment to overcome composite technological hurdles. Production efficiency need to be improved through advancement of biological treatment. An innovative technique that includes cell recycling, stabilization and multistage fermentation need to be employed.
- For the sustainable production of biobutanol, it is essential to focus on cultures of different species of bacteria. Additionally, fermentation improvements with severe strains may be able to produce a higher production rate of biobutanol.
- Integration of a recovery technology is crucial to minimize and overcome the mixing of inessential solvents that will ultimately reduce the operational cost of process. Operating costs, equipment cost, energy cost, microbial toxicity, and process integration are the key parameters of consideration in biobutanol recovery.

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