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Sustainable Biobutanol and Working towards the Green Gasoline of the Future

Yaser Dahman*

Department of Chemical Engineering, Ryerson University, Toronto, M5B 2K3 Ontario Canada

With world energy consumption predicted to increase 54% between 2001 and 2025, primary attention has been directed towards the development of carbon neutral energy and sustainable sources to meet the future needs [1]. Reductions of fossil fuels, environmental deterioration, and fluctuating prices of traditional fuels have revived an interest in the development of renewable fuels. Concerns regarding green house gas emission, energy scarcity and the desire for energy independence are increasing the pace and intensity of biofuel research and commercialization. Biofuels are an attractive substitute to current petroleum based fuels because they can be utilized as transportation fuels with diminutive change to current technologies; they also have significant potential to improve sustainability and reduce greenhouse gas emissions. Liquid (i.e., ethanol, butanol, biodiesel) or gaseous (i.e., methane or hydrogen) biofuels are generally produced from organic materials such as starch, oilseeds and animal fats or cellulose and agricultural biomass. While in some countries such as South Africa and Russia, ABE fermentation process remained competitive due to the low raw material and labor costs, it had lost competitiveness in other countries by 1960s, owing to the increase of feedstock costs and advancement of the petrochemical industry [2]. Since the late 1990s global biofuel research has steadily been on the rise, with new modified micro-organisms, pretreatments, process configurations and technologies, thereby improving conversion efficiencies and decreasing production cost. In first-generation biofuel, plant sugars and starch from food crops were fermented to biofuel by yeast. The advent of second-generation biofuels broadened the feedstock base to include non-food cellulosic biomass by incorporating chemical or enzymatic hydrolysis in various process configurations [3]. Third-generation biofuels employed enzyme-producing micro-organisms such as algae, to hydrolyze plant polymers and ferment the resulting sugars. The Canadian government supports the development of biofuel production through a $2 billion commitment in the 2007 Federal Budget. A long-standing federal and provincial excise tax exemption on renewable fuels has encouraged the renewable fuels to be competitive with gasoline. In the United States, according to a report from the Department of Energy (DOE) titled “Roadmap for Biomass Technology in the United States”, bio-based transportation fuels are projected to increase from 0.5% of U.S consumption in 2001 to 4% in 2010, 10% in 2020, and further to 20-30% in 2030, or about 60 billion gallons of gasoline equivalent per year. This is in addition to 10–12 billion pounds of butanol annually required for industrial energy consumption [4].

Although there was more focus on fermentation of ethanol due to its vast applications in industry, more interest has recently intensified on butanol for its similar characteristics to gasoline, which allow the direct use of butanol in any gasoline engine without modification and/or substitution [5]. More importantly, butanol can be mixed with gasoline in any proportion [6,7]. Interestingly, while the current automotive engine cannot tolerate more than 15% ethanol, n-butanol can be used up to 100% in unmodified 4-cycle ignition engines or blended up to 30% (70% diesel) in a diesel compression engine or to 20% (80% kerosene) in a jet turbine engine [8,9]; Butanol, a product of acetone-butanol-ethanol (ABE) fermentation, is an excellent feedstock chemical in the plastics industry, a food-grade extract in the food and flavor industry and more importantly, a superior fuel to ethanol [10,11]. Biobutanol is a biofuel that can be produced from renewable resources using special strains of bacteria such as *Clostridium acetobutylicum* or *Clostridium beijerinckii* [12]. The advantage of using these strains is that they can utilize both lignocellulosic hydrolysate sugars (hexoses and pentoses) in contrast to traditional ethanol-producing yeast strains that cannot do that [13]. As a biofuel, butanol has some interesting properties that other fermentation derived fuels do not have [14,15]. Butanol contains 22% oxygen which makes it an excellent fuel extender. It is more hydrophobic than ethanol and mixes better with hydrocarbon fuels. It is not sensitive to water, less volatile, less hazardous to handle, and less flammable than ethanol [16,17]. The lower vapor pressure makes it suitable for use as an oxygenator. Its adaptability and integration into the current transportation technology can revolutionize energy consumption and will contribute to climate change mitigation without having detrimental side effects on the environment. Moreover, using agricultural biomass as a renewable feedstock for biobutanol production improves food security, land use, and environmental protection Table 1.

Considering all recent technologies in microbial physiology, strain development, fermentation and low-energy fuel separation, biobutanol is the new generation of green biofuel that is cost-effective, burns clean, and enhances environmental sustainability. Whether it will be used as a standalone transportation fuel, an additive to gasoline or diesel fuel, or an additive to improve the properties of ethanol, biobutanol technologies offer a more sustainable and environmentally friendly future.

Fuel Property	Gasoline	Butanol	Ethanol	Methanol
Energy density (MJ/L)	32.00	29.20	19.60	16.00
Air-Fuel ratio	14.60	11.20	9.00	6.50
Specific energy (MJ/kg air)	2.90	3.20	3.00	3.10
Heat of vaporization (MJ/kg)	0.36	0.43	0.92	1.20
Research Octane Number (RON)	91-99	96-105	129	136
Motor Octane Number (MON)	81-89	78-89	102	104

Table 1: Properties of common fuels with respect to gasoline [19].

***Corresponding author:** Yaser Daman, Department of Chemical Engineering, Ryerson University, Toronto, M5B 2K3 Ontario Canada, Tel: 1 416-979-5000 ext. 4080; Fax: 1 416-979-5083; E-mail: ydahn@ryerson.ca

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