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PRODUCTION OF ETHANOL FROM BIOMASS – RESEARCH AND PERSPECTIVES

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ABSTRACT

Production of bioethanol from biomass plays an important role in terms of improvement of environmental situation and reduction of greenhouse gases emission. Bioethanol is identified as a sustainable solution of fossil fuel problem and it has gained significant attention with global production of 29 billion tones per year. The research interest in bioethanol is focused not only on the issues of energy crises but also on the comprehensive diversification of the economy. Converting biomass to bioethanol provides combined benefits of waste-to-value conversion and alternative fuel production. The objects of our research were samples of petroleum-based gasoline (Regular, Premium and Super brands), as well as 10%, 20% and 30% mixtures of bioethanol with gasoline. We prepared the following test samples: E0 and ethanol/gasoline mixtures E5, E10, d E20, and then studied their physical, chemical and technical characteristics. The group composition of these samples was studied on IR spectrometer and their individual composition – on gas chromatograph. During idle running of engine the text mixtures showed a decrease in CO content in exhaust gases by 15%. In addition, since the obtained mixtures contain oxygen, complete combustion of the fuel takes place. Thus, adding of bioethanol additive causes improvement of ecological properties of fuel.

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Introduction.

The main trend of fuel market development in the modern world is closely related to new bioenergy technologies which are likely to remain on the list of priorities of the global energy supply in the next 30-40 years. One of the best ways to improve environmental safety and ecology is to develop alternative renewable sources of energy. This is a clear trend in the energy development programs of the world's leading economies. In addition, the EU countries are striving to increase the share of renewable energy sources in the total energy balance to 20% and in some cases even more. After signing the cooperation agreement with the EU, Georgia also should harmonize its strategic goals and trends with those of the EU countries.

A potential solution of the problem of greenhouse gases emissions reduction, stabilization of global climate, and improvement of energy saving is a shift from traditional fossil fuels to green, renewable sources of energy. Key sources of renewable energy include solar, wind, hydro, geothermal and biofuel energy, each of which can provide energy services with low amount of greenhouse gases and air pollutant emissions [1, 2]. One of 17 sustainable development goals (SDG 7) set by the UN General Assembly is to ensure access to clean, affordable, reliable, sustainable and modern energy, which emphasizes the importance of international cooperation in relation to the increased use of renewable energy sources [3]. In addition, it can be said that as countries try to reduce poverty, they in turn increase urbanization and as a result become key contributors to the growth of greenhouse gas emissions. Currently 6 of 10 CO emitting countries are developing countries [4]. Therefore, the research and development in the sphere of renewable energy and related technologies are focused on making these alternatives economically viable and sustainable for all countries.

Biofuel is ecologically clean alternative fuel obtained from natural vegetable oils and/or animal fats, i.e. from the bioresources. Biofuel can successfully replace petroleum-based fuel in every sphere where it is used, including internal combustion engines. Biofuel can be used in standard diesel engines without necessity of their modification. It can be used alone and in the form of mixtures with petroleum-based fuel. Considering various sources of renewable energy it can be said that biofuel is possibly the best potential source of renewable energy in the transport industry. Biofuel can exist in solid, liquid, and gaseous forms; however, most of researches focus on liquid biofuel having the greatest potential for decarbonization and can be easily integrated with technology, existing in the sphere of transport industry [5]. Nowadays the bioethanol is the most widely used biofuel globally, accounting for approximately 80% of all liquid biofuel production [6, 7].

It is predicted that by 2024 the global production of biofuel (the so-called bioethanol) will exceed 135 billion L with the largest contributions from the USA (42%) and Brazil (31%) biofuel industries [8].

Since new millennium the rate of biofuel production in the EU constantly increased. In 2016 the total EU production reached 12.5 million tons. The new report of biofuel markets and technologies estimate steady growth between 2017 and 2021 as a result of higher petroleum prices, new feedstock availability, and advanced technologies.

According to BP forecast of energy resources the use of biofuels by 2040 will increase. This is shown on Figure 1.

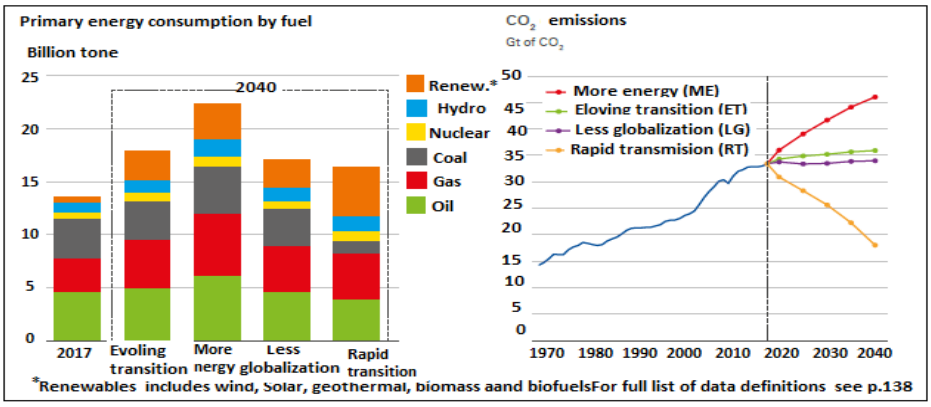

Figure 1. Forecast of energy resources until 2040 according to the BP Outlook [9].

Several key markets simulate the growth of biofuel production industry. Mandates for blending of biofuel with petroleum-based fuels now exist in at least 38 countries and 29 states or provinces around the world. The USA, Brazil and EU countries are three largest markets representing about 85 percent of global biofuel production today.

Georgia being a country entirely dependent on imported fuel needs to develop production of its own eco-friendly fuel, including biofuel. So, after signing an association agreement with EU it should harmonize its targets with requirements of EU in the sphere of environment protection. Tbilisi - the capital of Georgia with a population of up to 2 mln is overloaded with vehicles (approximately 1 mln vehicles move every day in the city). As a result the air of the town is heavily polluted and the main contributor to the air contamination is land transport. Most of municipal buses work on conventional gasoline fuel and they emit up to 65 tons of CO2 into the atmosphere. Biofuel is a high quality carbon-neutral fuel as the CO2 generated during combustion is balanced by the CO2 consumed by the plants during their lifecycle; therefore it can be used in any segment of industry where petroleum-based gasoline is used, including internal combustion engines. The physical and chemical characteristics of biofuel are quite close to those of conventional gasoline, but unlike petroleum-based fuel it is renewable, eco-friendly and carbon-neutral fuel. Since biofuel has a closed carbon cycle, it does not add CO2 and greenhouse gases to the atmosphere in contrast to petroleum-based products. Biofuel has many other benefits as compared to the conventional fuels including low sulfur content, high biodegradability, low toxicity, and low emissions. Biofuel can be used in standard internal combustion engines and their modification is not required. Biofuel can also be blended with conventional petroleum-based fuel. Biofuel is much better for the environment because it is obtained from renewable resources and has significantly lower emission than petroleum-based gasoline. Chemical similarity of biogasoline and conventional gasoline makes it possible to mix them completely and its formula does not to require modification of fuel supply system [10].

Experimental methods and materials.

The goal of our research was obtaining of ethanol fuel and biogasoline from agricultural waste. Bioethanol that can be used both as a fuel and as an additive to fuel was obtained by method of fermentation and extraction of agricultural wastes. As a rule fermentation is carried out by a process presented on Figure 2.

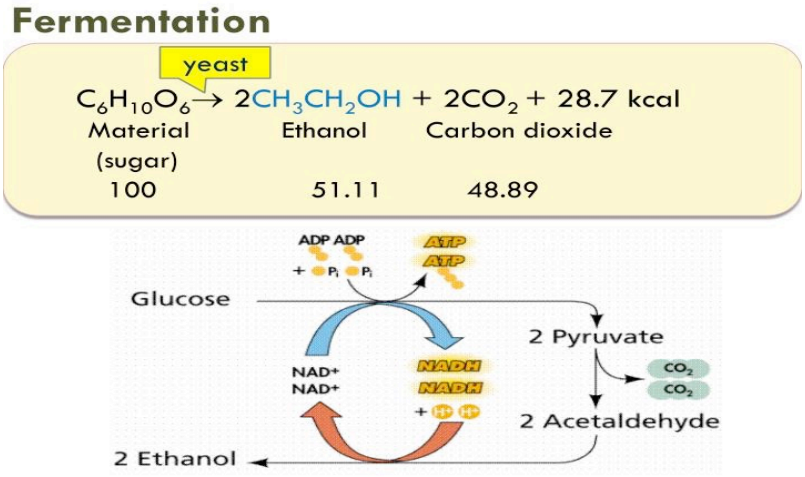

Figure 2. Obtaining of ethanol by fermentation process.

We obtained the ethanol fuel from biomass in laboratory conditions, prepared its E5, E10 and E20 blends with petroleum gasoline and studied their physical and chemical characteristics according to the requirements of EN 228 [11] and EN 15376:2014 [12] standards.

Results and discussions.

Comparison of physical and chemical characteristics of conventional petroleum gasoline and obtained fuel ethanol are presented in Table 1.

Since gasoline is intended to be used in internal combustion engines, the physical and chemical parameters and characteristics of the most widespread blend - E20 and pure gasoline E0 was analyzed and compared to those of conventional petroleum-based gasoline fuel meeting requirements of the EN 228 [11] and ASTM D 5798 [13] standards.

Table 1. Physical and chemical characteristics of gasoline and the obtained ethanol fuel.

Characteristics	Ethanol	Gasoline
Chemical formula	C_2H_5OH	C_8H_{18}
The composition	(C) = 52% (H) = 13% (O) =35%	(C) = 85% (H) = 15%
Boiling point, ^0C	78	30-225
Calorific value of Fuels, MJ/kg	29	45
Density, kg/m^3	785	745
Research octane number, RON	111	95
Motor octane number, MON	94	85
Latent heat of vaporization, kcal/kg	204	70–100

Physical and chemical characteristics of petroleum-based gasoline and biofuel blends E5, E10 and E20 were studied and the results of this study are presented in Table 2. [14, 15].

Table 2. Physical and chemical characteristics of petroleum based gasoline and E5, E10 and E20 biofuels.

Characteristics	Gasoline E0	Bio fuels		
		E5	E10	E20
Density at 15 ^{0}C, kg/m^3	720.0	722.0	740.0	760.0
Density ^{0}API Gravity	64.8	62.6	59.5	54.52
Research octane number, RON	93	95	96	98
Motor octane number, MON	83	85	86	88
Viscosity at 40 ^{0}C, mm^2/c	0.50	0.53	0.56	0.70
Determination of gum, mg/100 ml	3.5	3.2	3.0	2.5
Oxidation stability, minutes	360	360	360	360
Vapor pressure, kPa	45	50	60	70
Copper strip corrosion (3 hours at 50 ^{0}C)	Withstands	Withstands	Withstands	Withstands
Benzene content, %	2.0	2.0	1.0	0.8
Total Aromatics content, %	32.5	32.0	30.0	28.5
Sulfur content, mg/kg	50	47	45	40

The group composition of conventional gasoline, E5, E10 and E20 biogasoline blends was determined using IR spectrometer (PerkinElmer Spectrum 2). Comparison of IR spectra of E0 petroleum-based gasoline and E20 biogasoline is presented on Figure 3. The spectra of E20 and that of petroleum-based gasoline were identical, however, the gasoline/biogasoline blend is eco-friendly, not emitting harmful emissions.

When comparing physical, chemical and spectral parameters of conventional gasoline and bioethanol it became obvious that there was a possibility for further improvement of several characteristics and structural compositions of biofuel, which will be a subject of our future research. The effect of bioethanol on the ecological compatibility of the automobile engine was studied. The objects of research were Regular, Premium and Super brands of gasoline, as well as bioethanol test additive, which was added to gasoline in the amount of 10%, 20% and 30%.

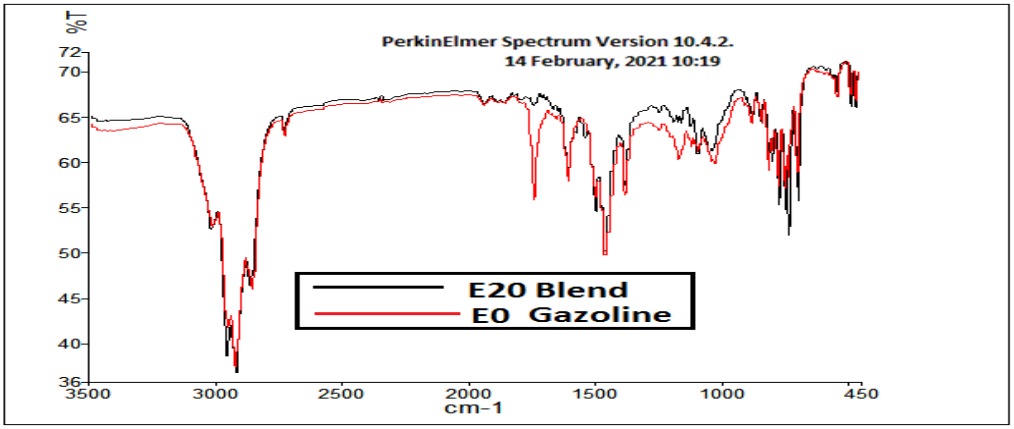

Figure 3. Comparison of IR spectra of gasoline (E0) and gasoline/bioethanol blend (E20).

Ecological properties of the test additive were studied on the test stand SAK670 (Germany), on which the engine and gearbox of BMW 316 motor vehicle was installed. The stand included brake and torque gauges, as well as crankshaft rotation frequency and fuel consumption measuring instruments. Studies showed that bioethanol was more effective than low-octane gasoline. It was

shown that the environmental properties of Super and Regular brands of petroleum-based gasoline improve upon addition of experimental bioethanol. For example, in case of using of 10-30% trial bioethanol as an additive to gasoline, the content of harmful components in the exhaust gases of the BMW 316 engine at idle running and at full load was reduced: CO 11÷15% and 10÷14%; CH 21÷25% and 20÷23%; NOx 7÷10% and 6÷9%, respectively. Influence of bioethanol on fuel capacity (Me, Ne), fuel consumption (G) and ecology (CO, CH, CO2, NOx) parameters of BMW 316 brand engine are shown in Table 3.3.

Table 3. Influence of bioethanol on fuel capacity (Me, Ne), fuel consumption (G) and ecology (CO, CH, CO2, NOx) parameters of BMW-316 brand engine.

Parameters	E20 (Gasoline + 20% bioethanol)			E30(Gasoline + 30% bioethanol)		
n, min $^{-1}$	1000	2500	3500	1000	2500	3500
Idling						
G, L/h	0,888	1.208	1.763	0.895	1.217	1.773
Me, nm	0	0	0	0	0	0
Ne, kvt	0	0	0	0	0	0
CO, %	0.90	0.74	0.57	0.87	0.72	0.56
CH, %	156	99	66	148	94	62
CO_2, %	12.5	12.6	12.9	12.3	12.5	12.7
NOx, ppm	77	287	478	76	284	472
Full load						
G, L/h	5.34	7.90	11.34	5.39	7.94	11.44
Ne, kvt	12.4	38.3	62.9	12.2	38.1	62,7
CO, %	0.53	0.48	0.38	0.54	0.47	0.37
CH, %	257	209	131	245	199	124
CO_2, %	12.2	12.4	12.7	12.1	12.4	12.5
NOx, ppm	1460	4368	4623	1429	4186	4523

For example, in case of using of 10-30% trial bioethanol as an additive to Rompetrol gasoline, the content of harmful components in the exhaust gases of the BMW-316 engine at idle running and at full load is reduced: CO 11÷15% and 10÷14%; CH 21÷25% and 20÷23%; NOx 7÷10% and 6÷9%, respectively. Especially noteworthy is the reduction of CO2, the main cause of "global warming", by 8÷14% and 10÷17%, respectively. This indicates the prospects for increased use of combustible ethanol. At the same time, the engine power decreases by 1÷2% and the hourly fuel consumption increases by 1÷1.2%. Taking into account that in this case the fuel contains 1030% of bioethanol, there is actually a reduction in the cost of base petroleum gasoline by about 8÷18%.

The comparison of spectra of conventional gasoline (E0) and its blends with bioethanol (E5, E10 and E20) makes it obvious that several major parameters of biofuel have been improved and its structural composition remained stable, the latter being very important.The group composition of the samples was studied on spectrometer (PerkinElmer Spectrum, version 10.4.2) and individual composition on gas chromatograph (Crystallux-4000M, equipped with NetChrom v2 software) according to the ASTM D7096 standard.

Based on the results of the research, an improved composition of biodfuel was identified, which, while meeting the requirements of EN 15376:2014 and EN 228 standards, can significantly reduce greenhouse gases and other harmful emissions.

Conclusion.

Biofuel is obtained in Georgia for the first time and according to our research results it can be used in vehicles equipped with internal combustion engines.For production of bioethanol the biomass and other agricultural wastes are used ensuring rational management of wastes, development of energy-saving technologies and improvement in ecological state of the environment. It was established that addition of 5-10% bioethanol fuel to petroleum-based gasoline provides normal operation of

BMV car engine without its modifying. In addition, since the obtained blends contain oxygen, complete combustion of the fuel takes place. And thus, adding of bioethanol makes it possible to improve the ecological properties of fuel.

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