Name of the project: Investigation of the energy potential of biomass obtained after the synthesis of organic substances for the purpose of its secondary and full use (AP09562068, Reg. No. 0121RK00534, Inventory No. 0221RK00412)

Relevance:

Currently, one of the main problems in the Republic of Kazakhstan is the problem of accumulating a huge amount of waste, both production and consumption. This is because ineffective waste management contributes to climate change and air pollution and directly affects many ecosystems and human health.

The amount of waste generated is closely related to consumption and production patterns. In this regard, the transformation of waste into a resource is one of the key goals of our country. In accordance with the Concept of the Republic of Kazakhstan, the task is set that by 2030 the share of waste recycling should be increased to 40%, by 2050 - to 50%.

Currently, landfills from manufacturing plants, considered the last resort in the waste hierarchy, emit very large amounts of methane, a powerful greenhouse gas associated with climate change. Methane is generated by microorganisms present in landfills from biodegradable waste such as food, paper and garden waste. Depending on how they are built, landfills can also pollute soil and water. Anything that is not recycled or recovered from waste represents the loss of raw materials and other resources during the stages of production, transportation and consumption of a product.

It should also be noted that about 60% of municipal waste sent to landfills is biodegradable and mainly consists of food waste. This makes biological treatments, such as composting, anaerobic and dark digestion, reasonable options for the disposal of these organic waste streams.

In the case of complex processing of organic waste into gaseous hydrogen, biogas-methane and other related products, the factories themselves may become consumers of their products. This will solve two problems at once: (1) to successfully dispose of organic waste, (2) to increase the plant's profit by generating and selling highly profitable products such as gaseous biohydrogen, biomethane, etc. In this regard, waste streams with a high content of organic substances (protein , carbohydrates or crude fat) must be used as raw materials for the production of various high value-added products, including gaseous biohydrogen and biomethane.

Research into the conversion of microbial biomass to produce hydrogen has progressed in recent years, but the efforts of scientists are focused on solving a number of problems. Key research and development areas include:

- Increase the rates and yields of hydrogen production in fermentation processes through a range of techniques such as improving microbial strains, optimizing the reactor system, and identifying raw material sources and processing methods with the highest yields.
- Development of hydrogen fuel cell systems that can be scaled up to commercially significant sizes while maintaining the performance and efficiency of the system observed in the laboratory and minimizing the cost of reactor components.

Considering energy security and the global environment, there is an urgent need to develop clean and renewable energy sources. On the other hand, hydrogen is an environmentally friendly energy carrier, and when burned, water is the only by-product. Anaerobic bioconversion of organic waste to hydrogen gas is an attractive option that not only stabilizes waste and wastewater, but also creates a favorable renewable energy carrier.

In this regard, an urgent direction is to study the energy potential of biomass by establishing the kinetics of biohydrogen production, depending on the characteristics of various substrates and processes, and to assess the potential for hydrogen production under various operating conditions.

The goal of the project is to study the composition and energy potential of biomass after obtaining biogas-hydrogen from deeply processed grain components for further production of various types of energy carriers.

Expected and achieved results:

All types of work have been completed according to the schedule. A literature review and patent research have been carried out:

- when studying the energy potential of biomass obtained from secondary products, including from post-alcohol grain stillage or its mixture with other carbon-containing secondary products, the acid hydrolysis method can be successfully used to obtain a hydrolyzate.

- for the secondary and full use of biomass in the production of energy products, including biohydrogen, the study of the biotechnological potential of the wild-type *Escherichia coli* bacteria and their mutants is of greatest interest. Since, *E. coli* is one of the most studied prokaryotic microorganisms; gram-negative bacteria; facultative anaerobic; and does not form endospores.

The parameters of raw material hydrolysis, anaerobic fermentation by various bacteria, biogas-hydrogen production and biomass formation have been worked out. In order to study the mechanism of biohydrogen release and biomass formation, the composition and concentration of raw materials and products of hydrolysis, anaerobic digestion were studied based on the analysis

of the following data: moisture content of raw materials; the total quantitative content of sugars in native raw materials; organic acids before and after hydrolysis, at the beginning and end of the biohydrogen yield; the quantitative content of sugars on HPLC before and after hydrolysis, as well as at the beginning and end of the biohydrogen yield; oxidation-reduction potential of the substrate during microbial fermentation; acidity of the substrate (confirmed by test reports).

Mathematical planning and evaluation of the reproducibility of experiments were carried out based on the results of a preliminary analysis of the hydrolysis process post alcohol grain stillage and/or its mixture with other carbon-containing secondary products. The adequacy of the calculated and experimental data was confirmed by the high value of the coefficient of determination. According to the data obtained, the rational yield of monosaccharides (glucose and fructose) and org. acids are achieved when the content in the substrates: from grain stillage 10% when treated with 1.5% acid; from brewer's grains 4% when treated with 1.5% acid; from molasses 10% when treated with 0.75% acid (confirmed by test reports).

Based on the above results of experimental studies, it can be stated that the data obtained are of great importance for the use of waste from the agro-industrial complex for obtaining biomass and bioenergy. It was shown that a mixture of PGS, BG, and CM increased the cumulative H2 production by ~ 2.7 times in multiple mutant strains. Moreover, the rate of H2 production was increased in the mutant strain by ~ 1.3-fold in the PGS assays. In addition, H2 production was increased in the waste mix compared to single waste. An appropriate mix of carbon sources, regulation of external parameters, genetic manipulation are important for the prolongation and improvement of the H2 production technology.

- Prepared and successfully defended graduate qualification works of students:

1) Sultanbek S. - master's thesis: «Substantiation of hydrolysis parameters of molasses-residue of sugar production in the production of biohydrogen»;

2) Sagandykova A. - bachelor's thesis: "Substantiation of parameters for obtaining biohydrogen from beer spent grains - beer production waste" - state attestation commission protocols.

Members of the research group:

Bekbayev Kairat - project manager, candidate of technical sciences, author ID in Scopus**:**57216826792, https://orcid.org/0000-0001-9591-0370

Toleugazykyzy Akerke - leading researcher, PhD student in specialty 6D072800 - "Technology of processing industries", author ID in Scopus**:** 57216832008, https://orcid.org/0000-0002-2061-1699

Akim Maya - junior researcher, master's student in the specialty "Food technology"

List of publications published under this project:

Published:

- Bekbayev K., Toleugazykyzy A.. Study of biomass formation during bioconversion of lignocellulose waste of production // XXV International Multidisciplinary Conference “Recent Scientific Investigation”. Proceedings of the Conference Primedia E-launch LLC, Shawnee, USA. October, 2021., P.22-25. https://www.internauka.org/authors/bekbayev-kairat

Submitted to Scopus (64 percentile):

- Bekbayev K., Mirzoyan S.,.Toleugazykyzy A, Tlevlessova D., Vassilian A., Poladyan A.; Trchounian K. Optimized growth and hydrogen production by *Escherichia coli* during utilization of sole and mixture of sugarcane, alcohol and beer production wastes // Journal Biomass Conversion and Biorefinery. Scopus.

Accepted in the magazine included in the Committee for Control in the Sphere of Education and Science, and Scopus database (percentile less than - 35):

- Toleugazykyzy A., Tlevlessova D., Samadun A., Bekbayeva R. Characteristics of the formation of biomass during the hydrolysis of lignocellulosic waste during the production of biohydrogen: the effect of various concentrations of the substrate and dilute acid on the yield of sugars // Eurasian Journal of Physics and Functional Materials.
- Bekbayev K., Akim M, Nabiyeva Zh. Biohydrogen production based on dark fermentation of molasses using *Escherichia coli* // Eurasian Journal of Physics and Functional Materials.

Information for potential users:

We invite the following persons to business cooperation:

- production enterprises of the food and processing industry for monitoring and research on the recycling of organic production and consumption waste;
- teams of scientists engaged in the development and improvement of hydrogen fuel cells for the joint study of the potential of gaseous biohydrogen obtained from various organic production and consumption wastes.