

Production of high protein supplementary feed from landfill gas

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Abstract. The article describes the problem of feed protein deficiency. The main sources of the methane for the biomass production are considered. The chemical composition, the haprin main characteristics and its production technological scheme are presented. The solid municipal waste volume disposed of annually at the landfills is estimated. The quantitative characteristics of atmospheric pollutant emissions from the JSC "Polygon" landfill (Vladimir region) are presented. It is proposed to use landfill gas as the main raw material in the haprin production. The haprin amount obtained during the operation of the JSC "Polygon" landfill was calculated. The economic benefits of this production were estimated

1 Introduction

The intensification of animal agriculture requires a sharp increase in the production of feed protein compensating for its lack in the traditional vegetable feed. 30 million tons per year is the deficit of this product in the world, while in Russia the shortage of feed protein currently exceeds 2.5 million tons per year [1].

The main way to reduce and eliminate feed protein deficiency is to produce biomass using microbial synthesis: strains of methane-oxidizing (methanotrophs for example *Methylomonas meyhanaica*, *Methylobacter tundripaludum*) and methane-producing (methanogen, for example, *Methanococcus capsulatus* bacteria). These bacteria have a record biomass accumulation rate thereby creating a large amount of protein. The biosynthesis process is less time-consuming and proceeds continuously regardless of the season and weather conditions while obtaining a protein that is stable in quality [2].

Currently experts from the different countries are actively studying the vital activity of the methanotrophic bacteria. For example, scientists from Calysta Inc. in California and String Bio in Bangalore (India) are developing new methods for converting methane to protein [2].

In Russia the largest producer of feed bacterial biomass from natural gas was the Svetloyarsk plant "Volgogradbiosytez" (Volgograd region). About 40.000 tons of haprin (short for "gas protein") were produced and sold during the period of its functioning from 1985 to 1994. From 1996 to 2006 the Norwegian company Norferm produced a complete analog of the haprin called "bioprotein" for feeding fish and farm animals using Soviet

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technology. The Danish company UniBio for the pilot installation development of modified Soviet technology the production of the bio proteins under the name "UniPrin" ("uniprotein") for use in feed and food products [1].

2 Materials and methods

The haprin compositionally is a high-protein product containing in terms of absolutely dry substance at least 70% of crude protein and also having almost all essential amino acids (total not less than 55%) (Table 1). The haprin also has lysine 4.0 - 5.3%, sulfur-containing amino acids (serine, methionine) - 1.7%. The haprin contains a large amount of vitamin B complex: thiamine (B1) - 14.1 mg/kg, cyancobalamin (B12) - 5.6 mg/kg and micro and macro elements. Also it is non-toxic, does not have carcinogenic and cumulative effects [3].

Table 1. The amino acids included in the haprin.

Amino acids	Content, %	Amino acids	Content, %
lysine	4.0 – 5.3	histidine	1.7 – 2.5
tryptophan	1.4 – 1.6	aspartic acid	5.3 – 5.8
arginine	2.3 – 3.5	threonine	2.4 – 3.0
serine	1.2 – 2.3	glutamic acid	6.8 – 7.8
proline	2.3 – 3.1	valine	4.1 – 4.2
alanine	4.2 – 4.8	leucine	4.5 – 4.9
cystine	0.3 – 0.5	phenylalanine	2.3 – 2.9
isoleucine	2.6 – 3.0	methionine	1.3 – 1.7
tyrosine	1.6 – 2.1	glycine	3.0 – 3.8

The haprin is a full-fledged substitute for an animal protein in contrast to an animal feed (including cereals and legumes). It provides balanced amino acid nutrition of animals, birds and fish. For example it contains 5 times more protein than barley or oats. The haprin is superior to fishmeal and soybean meal in its nutritional value and balance in amino acid composition.

The haprin production is based on the implementation of cultivation processes in bioreactors of various designs using non-pathogenic strains of methane-assimilating cultures. The bacteria of the genus *Methylomonas*, *Methylococcus*, *Methylocystis*, *Methulosinus*, *Methylobacter* can be used as methane-assimilating cultures by continuously supplying oxygen-containing gas (the air, the oxygen-air mixture, the oxygen) and methane-containing gas (the natural gas, the methane) to the bioreactor. Further stages of processing the resulting biomass are traditional and include processes of concentrating cells from biosuspension, thermal sterilization and drying to obtain the finished product in the form of powder or granules [4, 5].

The technological process of obtaining haprin is continuous and consists of the following main stages:

1. The preparation of a nutrient substrate and the cultivation of seed pure culture.
2. The biomass fermentation.
3. The culture fluid separation.
4. The microbial suspension thickening.
5. The biomass inactivation.
6. Drying, packaging, packaging of the finished product.
7. Recycled process water purification.

To ensure the main technological process stages, auxiliary production stages are provided as part of the installation: reception, preparation of solutions and supply to the fermenters of ammonia water, phosphoric acid, salts and other chemicals in the required

CO [11, 12]. Moreover since the LG composition includes carbon dioxide before it is fed to the fermenter it is necessary to purify carbon dioxide.

As the study object for calculating the annual LG emissions from the landfill we took the JSC “Polygon” landfill (55.930125, 39.709838) located in the Vladimir Region on the border of the Petushinsky and Sobinsky districts about 3 kilometers from the village of Boldino and Babanino and 1.300 meters northwest of the M7 highway The Volga (Fig. 2).

The JSC “Polygon” landfill is a recess relatively isometric in shape a width of about 90 meters and elongated from west to east by about 150 meters.

This landfill began to operate on January 1, 2015. The amount of waste disposed per day is 1000 tons. The landfill area in the modern kennel is 17 hectares.

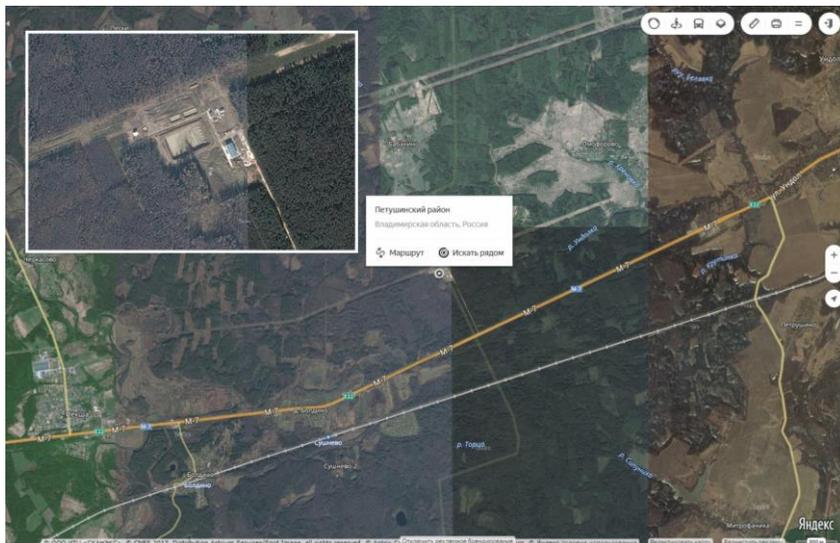


Fig. 2. The JSC “Polygon” landfill location.

The pollutant emissions calculation from the landfill was made based on the "Methodology for calculating the quantitative characteristics of atmospheric pollutant emissions from the solid municipal and industrial waste landfills" [13].

To carry out the calculation we used the data obtained including from the operating organization. The data are shown in table 2.

Table 2. The data used in the calculation

Data	Value
Average importance of MSW	47 %
Organic content in waste, total	55 %
lipoid	2 %
carbohydrate-like	83 %
protein	15 %
Average monthly temperature for the warm season	15 °C
Number of warm days	228 days
Duration of the warm period (more than 8°C)	5 months
Duration of the cold period (from 0°C to 8°C)	7 months
Amount of waste disposed per year	365 000 tons
Start of landfill operation	2015 year
End of landfill operation	2022 year

3 Results and discussion

As a result of the calculation made on the Methodology basis, the specific yield of the landfill gas was 0.17 kg/kg of waste. Moreover the complete fermentation period of the waste organic part is 20 years.

Main characteristics:

- the quantitative LG output - 8.6 kg / t of waste per year;
- the methane percentage in the total LG volume - 52.9%.

Also table 3 shows the values of the maximum one-time and the gross emissions of LG components.

Table 3. Maximum single and gross emissions of landfill gas components.

Component	Maximum single emission, g/s	Gross emission, t/year
Methane	420.61	15 585.63
Toluene	5.75	212.95
Ammonia	4.24	156.99
Xylene	3.52	130.48
Carbon Monoxide	2.00	74.22
Nitrogen dioxide	0.88	32.69
Formaldehyde	0.76	28.28
Ethylbenzene	0.76	27.98
Sulfur anhydride	0.56	20.62
Hydrogen sulfide	0.20	7.66

During the 5 years of the landfill's operation the gross methane emission amounted to 77 928 tons. Given that from 1.6 m³ of methane 1 kg of haprin is obtained, from the landfill gas of the JSC "Polygon" landfill would be possible to produce 72 889.9 tons of haprin (taking into account methane losses of 30% with gases) from 2015 to 2019.

The cost of production of 1 kg haprin is 41 070 rubles taking into account the raw materials cost, wages, amortization and other additional costs. At the same time the market price of 1 kg haprin is 90 000 rubles. In this regard the economic benefit in the high-protein product production from the methane of the landfill is about 713 million rubles per year or 3.567 billion rubles over five years.

4 Conclusion

The methane using from the landfill as the main product for the haprin production is due to the significant annual volume of LG formation, minimizing the landfill's negative impact on the environment, the high quality of the resulting feed product as well as economic benefits.

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