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Comparing the environmental impact of disposal methods of sugar production waste by simulation modeling

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Abstract

Currently, in Russia there is no established system of sugar waste treatment, while their forming is increasing every year. However the waste of sugar production is a valuable raw material that can serve as a source of energy and commodity goods, and their placement in landfills increases the irreversible climate change. The relevance of agricultural waste treatment is confirmed by the existing legal acts, such as the Doctrine of Food Security and Climate Doctrine of the Russian Federation, as well as the State programs of agricultural development. The given study focuses on comparison of environmental impacts and economic costs and benefits of four scenarios of processing of sugar production waste such as placing at the landfill, incineration, accelerated anaerobic digestion and the production of secondary product, a valuable food ingredient – pectin. The research method for examination of the scenarios is simulation modeling.

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Keywords: simulation modeling; life cycle; environmnetal impact categories; sugar beet pulp; waste; disposal; processing

1. Introduction

When processing sugar beet such types of waste as beet pulp (70–90 % by weight of beet), turnip (50–70 %), filter cake (8–12 %) and molasses (4–6 %) are formed. The total amount of sugar beet processing waste generated annually is about 30 bill tons [1]. The waste sugar beet pulp is most frequently exposed to processing, mostly it is to be disposed

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at landfills for municipal solid waste, but there are other methods. The most common ones include aerobic and anaerobic digestion, incineration, use as feed additives in animal diets and processing to produce pectin.

Incineration of sugar beet pulp to produce energy is impractical due to its low calorific value. The negative impact of waste incineration is the formation of ash (about 5 % by weight of incinerated waste) and emissions of carbon dioxide and monoxide, nitrogen oxides, sulfur dioxide, particulate matters and benzo (a) pyrene [2, 3].

Aerobic digestion or biocomposting is accompanied by heat release, where the food waste is exposed to aerobic biodegradation by microorganisms at an elevated humidity and temperature 400 °C. The compost can be used as organic fertilizer. The feature of this method of disposal is that the carbon and nitrogen content is proportional of the feed raw material. In this regard, the loading beet pulp in compost pits or bioreactors is not resulting in formation of good quality compost, which greatly limits the application of this method.

Anaerobic digestion is performed at medium and high temperatures in the reactor (digester), whereby a high-quality compost and biogas are formed. In normal operation the reactor produces biogas comprising 60–70 % of methane, 30–40 % of carbon dioxide, small amounts of hydrogen sulfide, as well as impurities of hydrogen, ammonia and nitrogen oxides. Per a one ton of wet organic waste 80 m^3 of biogas is produced [4–6].

Sugar waste processing to produce pectin is a complex process including hydrolysis, pressing, crushing the pulp and other ways of handling it, including the use of chemical solutions. The final product of the processing, pectin is a dietary supplement, registered under the code E440. Pectin is applied in the pharmaceutical industry as an additive to medicines for mitigating or enhancing action and also for production of capsule shells medicines; in the cosmetic industry as stabilizers for gels, creams and similar products; as well as in the confectionery industry for the purpose of production of sweets, desserts, marshmallows, jelly marmalade and edible coatings [7–11]. Estimated daily demand for pectin is about 2–4 g for one person and, therefore, the annual demand for it for the Russian population is about 110 ths tones per a year. In the absence of plants for production of pectin in Russia companies using pectin currently buy it abroad, particularly in China, the United States, Denmark, Germany and other countries.

2. Research method: simultaneous modeling as the research method for waste management

The aim of the study was to compare the environmental impact of the four scenarios of utilization of beet pulp: A – landfilling; B – dumping at the landfill of municipal solid waste, equipped by biogas extraction system; C – accelerated anaerobic digestion and D – processing of beet pulp to produce pectin. In all the scenarios the stages of crop production, harvesting and processing of sugar beet remained outside the production system boundaries (Fig. 1).

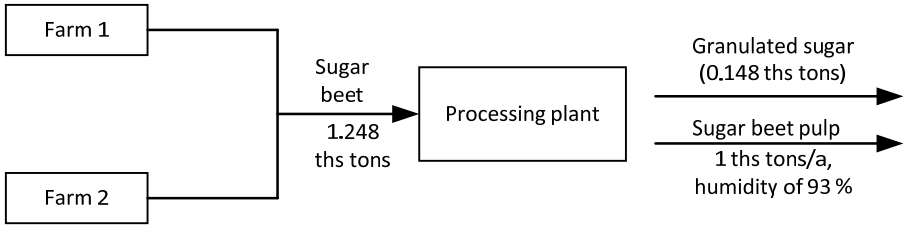

Fig. 1. Creation of sugar beet pulp at processing enterprises.

The concept "simultaneous modeling" is understood as a tool used for predicting and comparing the situations (scenarios) that lets to forecast the consequences of alternative courses of action and indicate which of the actions should be shown preference. Process of simulation modeling consisted of the following steps: definition of the system boundaries (Table 1), formulation of models, preparation of input data, translation of models, interpretation of the results and further implementation of scenarios [12].