The use of organic waste of the agro-industrial complex for the production of fuel using neural network algorithms

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Abstract. The article addresses the problem of processing organic waste from the agro-industrial complex. To solve the problem of processing biomass, it is proposed to use gas-generating units that convert the resulting biomass into biogas. Particular attention is paid to the principles of operation of gas generators, the description of the stages of gasification, and the ongoing chemical processes. The scientific novelty lies in the proposal for the introduction of intelligent technology based on artificial neural networks to predict product quality and control the gasification process at each stage. As a result of the study, it was revealed that the use of information technology contributes to the optimization of the production process.

1. Introduction
Agriculture in Russia has been one of the most actively and successfully developing sectors of the Russian economy since the 2000s. In 2016, for the first time in the past 50 years, Russia displaced the United States from the first place and became the world leader in wheat exports. Russian exports amounted to 24-25 million tons in 2016. In 2017, a record-breaking grain harvest in Russia was collected and it amounted to 135.5 million tons [1]. The agricultural sector in Russia is developing steadily, but many issues remain unresolved. One of the current problems of the industry is environmental problem. Agricultural production annually produces 250 million tons of waste, 150 million tons of which are in livestock and poultry farming and 100 million tons of which are in crop production [2]. Waste is not subject to cleaning, disposal and recycling. They poison the atmosphere and water bodies. Over two million hectares have been allocated for landfills for agricultural waste. Also, the costs of transporting waste to landfills are very impressive.

In this regard, the problem of the negative impact of agriculture on the environment requires a solution. It is necessary to develop resource-saving technologies in all areas of activity, that are related to food supply of the population. It should be noted that such technologies must also comply with environmental requirements.

2. Materials and methods
Today, the global demand for renewable energy sources is a key factor in the revival of the use of gasification systems. Such systems are successfully used for energy production from biomass. They are also an alternative to well-proven heat treatment systems for recovering energy from solid waste. Waste that cannot be biodegradable, such as agricultural waste, can be converted into usable fuel through a process called gasification.
Gasification is a thermochemical process that converts solid biomass into a mixture of combustible gases that can be used for thermal purposes. The gasification process is a series of chemical reactions. The chemical-kinetic model shows that the degree of completion of the reaction depends on the temperature and duration of the reaction. Gasification of solid biomass converts it into gas, which is often called a generator gas. Generator gas is mainly composed of CO, CO$_2$, CH$_4$, H$_2$ and N$_2$. The combustible gas components are CO, H$_2$ and CH$_4$. The production gas obtained from biomass can be used in an internal combustion engine with some modifications. For example, spark ignition (SI) engine can run entirely on generator gas. And a compression ignition (CI) engine replaces 60-80% of the fuel oil by using generator gas [3].

The process that takes place in a downdraft gasifier can be divided into four zones (figure 1). Dry zone 1 receives a solid carbonaceous material that is dried in the exhaust gases leaving the apparatus through the same zone. The solid carbonaceous material is heated and pyrolyzed. Meantime, the biomass breaks down into charcoal, resinous gases and vapors of resins in a liquid state. Pyrolysis is the heating of biomass in the absence of oxygen. In combustion zone 2, air is supplied in a sufficient quantity for combustion. Most of the resulting tar and coal is burned or cracked and generates heat to operate recovery zone 3. Combustion zone 2 passes carbon dioxide (CO$_2$) or water vapor (H$_2$O) through a bed of hot coal (C) in reduction zone 3. The carbon in the hot coal reacts with oxygen in the reduction zone 3. Carbon has a chemical affinity for oxygen, so it displaces oxygen from water vapor and carbon dioxide and redistributes it to as many single bond sites as possible. Reduction stops when all available oxygen is redistributed as individual atoms. Through this process, carbon dioxide CO$_2$ is converted to carbon monoxide CO.

**Figure 1.** Downflow Gasifier:
1 - Fuel inlet
2 - the Air intake
3 - Gas outlet
4 - Gasification zone
5 - Coal zone

Factors that affect the gasification process:

- Equivalence coefficient;
- H / C ratio;
- Ash content;
- Elemental composition;
- Content of volatile substances;
• Moisture content.

The equivalence coefficient determines the temperatures in the recovery zone, the yield and composition of the resin, and the calorific value of the gas. The H / C ratio is a measure of the vapor content of the gas inside the gasifier. Ash content is expressed in the same format as moisture content. This property is especially important in high temperature gasification, as molten ash can cause problems in the furnace.

The elemental composition of biomass includes carbon, oxygen and hydrogen. Most biomass can also contain small amounts of nitrogen. Volatiles are mainly indicative for gases other than water. Biomass feedstock contains a very high proportion of volatile organic compounds.

Moisture content is the amount of water in the biomass, expressed as a percentage of the mass. Biomass materials exhibit a wide range of moisture content. This affects its value as a fuel source. If the moisture content is excessive, the combustion process will not be self-sustaining.

Biomass gasification with air is possible under the following conditions:

• The equivalence coefficient must be in the range from 0.25 to 0.30;
• H / C ratio - about 2.2;
• The temperature in the recovery zone is above 800˚C.

The gasifier can use biomass, briquettes or coal as fuel. Biomass selection is based on calorific value, carbon content, oxygen content, hydrogen content and ash content. These components confirm the quality of the combustion gas composition. A briquette is a compressed block of coal dust or other combustible biomass material (for example: charcoal, sawdust, wood chips, peat, waste). Drying of biomass is one of the most common methods for producing briquettes [4].

3. Results

The quality of manufactured products can be improved by mathematical modeling of the processes that take place in power plants. Mathematical models of processes are built on the basis of solutions of differential equations systems that describes technological processes.

Creation of artificial intelligence algorithms, or neural networks, is one of the types of the mathematical modeling. Artificial neural networks are the software and hardware implementation of a mathematical model, which is built on the principle of networks of nerve cells of a living organism. The structural diagram of a neural network is showed on the figure 2 [5].

![Figure 2. The structural diagram of a neural network.](image)

Neural networks can learn, make generalizations and inferences, reveal hidden relationships and model highly volatile data and variances needed to predict rare events. An ability to learn is one of the
main advantages of neural networks over traditional algorithm. Technically, training consists of finding the coefficients of connections between neurons. Every neuron consists of four types: input values, weights and bias, activation function and output layer, the structure of neuron is on the figure 3 [6]. Input values are passed to a neuron using input layer. Weights are array values that are multiplied by their corresponding input values. The sum of these multiplications is called the weighted sum. The bias value is then added to the weighted sum. This allows to get the final prediction value of the neuron. The activation function determines the state of the neuron: activated or not. The output layer gives the final result of the neuron. This result can be used as the final output or passed on to other neurons in the network.

![Figure 3. The structure of neuron.](image)

A mathematical neuron model is given in formula (1):

$$s = \sum_{i=1}^{n} w_i \cdot x_i + b, y = f(s)$$

Where $w_i$ is the weight of the synapse, $i = 1...n$; $b$ is the bias value; $s$ is the sum result; $x_i$ is the component of the input vector (input signal), $x_i = 1...n$; $y$ is the output signal of the neuron; $n$ is the number of inputs of the neuron; $f$ is the nonlinear transformation (activation function) [7-8].

4. Discussion

The biomass of the agro-industrial complex can be used as a raw material for fertilizers, feed or fuel if there is an appropriate sorting and recycling system. Gasification is a biomass utilization method that converts biomass into carbon monoxide (CO), hydrogen (H$_2$) and carbon dioxide (CO$_2$). Crop waste can be used as a fuel source. Straw and husk of cereal crops, corn and sunflower are used in the form of fuel briquettes and have a calorific value when burning about 16 MJ / kg. In comparison with this, the calorific value of wood is on average 17.5-19.0 MJ / kg. Thus, crop residues can serve as a fuel source for most rural areas that have low forest cover and cannot use natural gas. In some European countries, straw briquettes have long been used as an efficient fuel source. This article proposes its own technology for the disposal of waste with the production of gas, fertilizers, and pressed building materials. The technology is based on the use of gas generators and the use of a machine learning process.

Agriculture in Russia is a large sector of the Russian economy. The share of agriculture in gross value added in Russia was about 4.5% according to statistics for 2016. 9% of the population was employed in agriculture in 2015. The volume of agricultural production in Russia amounted to 5.7 trillion rubles (about $100 billion) in 2017. The leading industry is crop production. It accounts for 54% of agricultural production. The share of livestock is 46%. Agricultural organizations occupy 53% of all farms, 35% of households and 13% of farmers. The value of gross agricultural output in 2018 reached 5.11 trillion rubles. Russia is a major exporter of agricultural products. Grain is a leader in exports, accounting for 27% of supplies in the first half of 2020 [9-10].
Despite the large volumes of export, its structure leaves much to be desired. The main share of exports is made up of raw materials in the crop and livestock sectors. At the same time, the opportunity to increase exports in monetary terms through deeper processing of raw materials in Russia remains unused. Russia is exporting record volumes of grain. And at the same time, Russia is importing the most important products of grain processing, which are used in the production of feed. There is a problem of processing waste from such large production volumes. The total amount of agricultural waste reaches 630-650 million tons. The largest part of the waste falls on the livestock industry (56%), the second place is occupied by crop waste (35.6%) [10]. The existing system of agricultural waste management requires a radical restructuring and the use of cost-effective Russian anaerobic biotechnologies, using which waste is rendered harmless and converted into organic fertilizer and biogas.

Waste from livestock and poultry farming is a serious threat to the environment due to a number of factors, such as:

- High toxicity;
- Significant amounts;
- Depreciation of storage facilities;
- Late collection;
- Untimely disposal of waste.

However, production waste can change its social utility with the introduction of progressive technological processes, advanced technology, new types of raw materials and with a change in demand for the products produced. Raw materials that are not used can become the source material for obtaining other final and intermediate products, as well as become an object of purchase and sale.

5. Conclusion
A product quality prediction model has been proposed to improve the product quality of a gas generator unit. The model is based on tracking the dynamics of ongoing processes. The model is built on the basis of temperature measurements and measurement of the content of chemical compounds released during the gasification process. The temperature is recorded using thermocouples located in the zone of active chemical reactions. The content of carbon dioxide and carbon monoxide is recorded using gas analyzers located in the gas path of the unit. The use of a neural network algorithm capable of predicting the quality of the resulting fuel is proposed. The algorithm is capable to adjust the technological process at each stage of it by changing the air supply to burning in order to obtain the highest specific heat of combustion.

The use of neural networks allows to reduce the time of processing the readings of thermocouples and gas analyzers, as well as increase the objectivity of determining the amount of air that must be supplied at different points in the gasification process. The disadvantages of using neural networks include the need to install gas analyzers on the gas path and the insufficiently wide temperature range that these devices can withstand. As a result, the analysis of the gas mixture may require the use of more expensive equipment [11-12].

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