Integrated model of agricultural production through the use of non-waste technologies based on microorganisms

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Abstract. The study developed and experimentally substantiated a model of a waste-free agricultural enterprise based on the application of biotechnology. The key element of the model is the production of effective microorganisms (EM preparations) in a fermenter and their use for waste processing, as well as for the production of feed additives, fertilisers and biogas. The efficiency of EM preparations application in animal husbandry and crop production has been experimentally shown. The data on increase of animal productivity, such as weight gain of young animals, milk yields of cows and egg production of chickens, as well as increase of crop yields have been obtained. The developed model allows not only to reduce the amount of waste, but also to increase the economic efficiency of agricultural production. The study demonstrates the prospect of using biotechnology to create sustainable and highly productive agricultural systems that help to reduce the negative impact on the environment.

1 Introduction

There are many approaches and ways to solve the problem of agricultural waste, each of which has its advantages and disadvantages. One of the most promising directions is the transition to organic agriculture based on the principles of sustainability, environmental safety and closed production cycles [1, 2]. The use of organic fertilisers, such as compost and biohumus, can increase soil fertility, reduce the need for mineral fertilisers and reduce environmental impact. However, organic farming requires more intensive labour and its yields may be lower compared to intensive farming, especially in the initial stages [3, 4]. Another solution is the introduction of technologies to convert waste into useful products such as biogas and compost. Biogas plants can convert organic waste into biogas that can be used to produce electricity and heat, reducing dependence on fossil fuels and reducing the amount of greenhouse gases in the atmosphere. However, the construction and operation of such plants requires significant investment and infrastructure. An alternative direction is the use of biological methods of plant protection against pests and diseases, such as the use of predatory insects, microorganisms and biopreparations, which reduces the use of chemical pesticides but requires more careful monitoring and control.

In the framework of solving the problem of agricultural waste, the proposed model of a waste-free, high-value agricultural enterprise based on the application of biotechnology is highly relevant and important. It offers an integrated approach to waste processing based on the use of efficient microorganisms. This approach is aimed at obtaining a range of valuable products, including protein feed additives, fertilisers and biogas, while minimising the negative impact on the environment and contributing to the creation of closed production cycles. The use of EM preparations can increase the efficiency of waste processing, reduce the cost of fodder and fertiliser production, and improve soil fertility and product quality. This approach not only solves environmental problems associated with waste [5, 6], but also provides economic benefits for agricultural enterprises by reducing costs and generating additional profit [7-9].

The introduction of such technologies opens new perspectives for the development of sustainable agriculture capable of ensuring food security while preserving the environment.

The aim of the work is to develop a model of a waste-free high-yield agricultural enterprise based on the application of biotechnology, which will allow efficient waste processing, production of valuable products, increase the economic efficiency of agricultural production and reduce its negative impact on the environment. The model includes a fermenter for the production of EM preparations, plants for grain processing and production of protein feed additives, as

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well as a bioenergy system [10, 11]. The proposed model is a holistic system that can be adapted to different types of agricultural enterprises and climatic conditions, and contribute to the transition to a more sustainable and environmentally friendly agriculture.

2 Method and materials

Within the framework of this research, a model of a waste-free high-yield agricultural enterprise based on the integrated use of biotechnology for processing agricultural waste and producing valuable products was developed. The basis of this enterprise is a fermenter with a capacity of 10-30 tonnes per month, where effective microorganisms (EM preparations) are cultivated. These preparations play a key role in waste treatment [12] and production of valuable products, and are the cornerstone of the whole system.

The plant growing block of the enterprise is represented by a variety of crops, including cereals, vegetables (both open and closed ground), as well as technical crops. An important aspect is the presence of a fruit and berry nursery, as well as the cultivation of topinambour and amaranth as additional sources of nutrients and raw materials. The main purpose of crop production is to provide raw materials for the livestock block and other production units, but also to produce marketable products for sale.

The processing block is represented by several workshops. The cereal processing unit includes a mill and a mini-bakery, which allows the production of flour, bread and confectionery products. The shop for preparation of feed mixtures is engaged in the production of mixed fodder, premixes and probiotics based on EM preparations and processed grain. There is also a shop for processing vegetables, berries, meat and milk, which makes it possible to produce a wide range of food products.

The livestock block includes a farm and a poultry house. Animals and poultry are provided with fodder of own production, including protein feed additives produced with the use of EM technologies. This reduces the cost of livestock production and improves its quality. The livestock block also includes a fish breeding pond, which diversifies production and provides an additional source of protein.

Waste generated during the production process is not discarded, but is sent for recycling. The waste processing unit includes a composting area, where organic waste is converted into valuable fertiliser, which is then used in crop production. An important element of the system is the bioenergy station (BES), which uses biogas obtained from waste to produce heat and electricity, as well as motor fuel. Thus, the enterprise provides itself with energy and reduces dependence on external sources [13].

All production processes at the enterprise are interconnected and closed in a cyclic system. This means that the waste of one process is a raw material for another, ensuring the waste-free and sustainability of the whole system.

The general scheme of experimental work included several stages aimed at modelling the functioning of the main elements of the proposed enterprise and assessing their efficiency. First of all, the possibility of creating and functioning of a fermenter for the production of effective microorganisms (EM preparations) was investigated, and the conditions of their optimal cultivation were studied. In parallel, experiments on the processing of grain raw materials to produce protein feed supplements were carried out at low-power plants, including probiotisation and autolysis processes. In addition, potential applications of EM preparations in crop, livestock and poultry production were investigated to assess their impact on crop yields, productivity and animal health.

A range of specialised equipment was used during the study. The fermenter was used to cultivate various strains of microorganisms, including yeasts, lactic acid, nitrogen-fixing and photosynthesising bacteria, and fungi, for the production of EM preparations. The fermentation process was carried out under controlled conditions, with regulation of temperature, pH, aeration and fermentation time. The fermenter operating modes varied depending on the specific type of microorganisms and the purpose of production. Fermentation parameters were monitored to cultivate different types of microorganisms and optimise their growth. Further, for the production of protein feed additives, low capacity units designed for processing of grain raw materials were used. The productivity of the plants was 1-1.5 tonnes per day. Within the framework of researches the equipment for granulation and drying of protein feed additives was used. The properties of the obtained products and cultivation parameters were also analysed. Within the framework of modelling the process of grain processing to obtain protein feed additives, experiments on probiotisation and autolysis were carried out, for which special devices and laboratory equipment were used. In addition, the impact of feed additives on the weight gain of young animals, milk yield of cows and egg production of hens was investigated.

3 Results and discussion

The experimental work included several stages. At the first stage, modelling of the process of production of effective microorganisms (EM preparations) in the fermenter was carried out. For this purpose, different strains of microorganisms were used, including yeast Saccharomyces cerevisiae, lactic acid bacteria Lactobacillus plantarum, nitrogen-fixing bacteria Azotobacter chroococcum, and photosynthetic bacteria Rhodobacter capsulatus. The experimental work included the evaluation of their growth and multiplication under different culturing conditions such as temperature (25-35°C), pH (5.5-7.0), aeration (aerobic and anaerobic fermentation) and duration of cultivation (24-72 hours). Different nutrient media including grain processing waste, molasses and whey waste were used to optimise the process. At the second stage, studies were conducted on the processing of grain raw materials to

produce protein feed additives. For this purpose, small capacity plants (1-1.5 t/day) were used, in which the processes of grain probiotisation and its subsequent autolysis were carried out. Bacillus subtilis and Lactobacillus acidophilus strains were used as probiotics. Probiotisation was carried out by introducing microorganisms into moistened grain with subsequent incubation for 12-24 hours at 30-35°C. Autolysis was carried out by heat treatment of grain followed by addition of enzyme preparations and incubation for 24-48 hours at 40-50°C. At the third stage, studies were conducted to evaluate the effectiveness of EM preparations and protein feed additives in crop and livestock production. In crop production, EM preparations were used for seed treatment, plant spraying and soil irrigation. In animal husbandry, protein supplements were introduced into the diets of calves, cows and chickens. Control groups received traditional diets without biotechnology application

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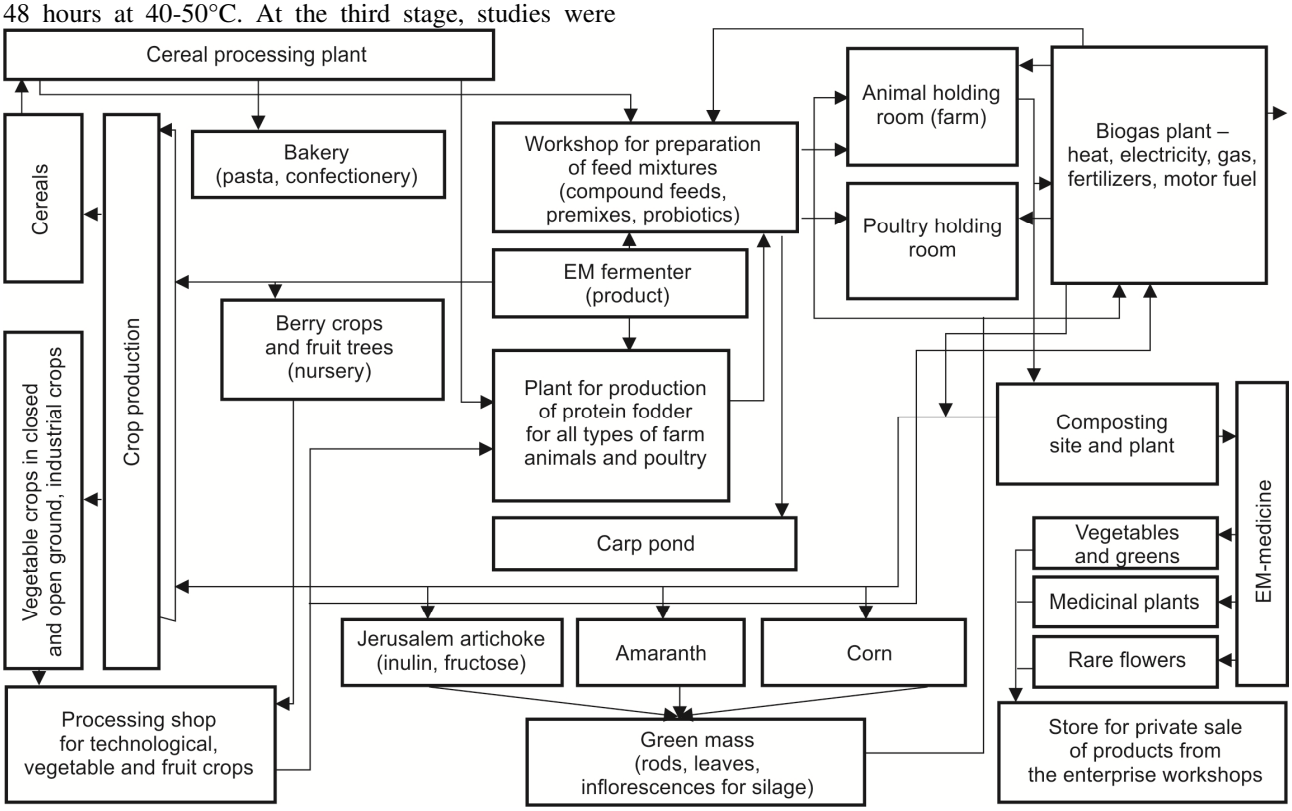

Figure 1. Schematic diagram of the model of a waste-free agricultural enterprise with application of biotechnologies

The results of the conducted studies showed high efficiency of the proposed model (Fig. 1). In particular, it was found that the fermenter succeeded in obtaining viable biomass of EM preparations with a titre of 107-108 CFU/ml. The optimum culturing conditions for different strains differed slightly, but common was the adherence to a temperature regime in the range of 28-32°C, pH 6.0-6.5, and aerobic fermentation for 36-48 hours. According to the results, the addition of molasses to the nutrient medium increased biomass yield by 15-20%. Grain processing plants produced protein feed supplements containing 25-30% crude protein. Probiotisation of grain increased the content of biologically active substances in the finished product by 10-15%, such as B vitamins, organic acids and amino acids. Autolysis of grain increased protein digestibility by 15-20%. The combined use of probiotisation and grain autolysis contributed to the production of a protein feed supplement with higher protein content and better digestibility. In calf feeding studies, protein feed additives replaced 25% of whole milk in the diet of calves, with average daily weight gain of 700-780 g, which is 8-10% higher than in the control group. At the same time, the cows receiving protein supplements in the diet showed an increase in milk yield by 4.2-5.8 litres per day, which is 12-18% higher compared to the control group, and milk fat content increased by 0.5-0.6%. When using protein feed additive in the diet of laying hens, egg production increased by 18-22% and egg weight by 4-5%. In crop production, EM preparations used for seed and soil treatment helped to increase the yield of grain crops by 10-15% and vegetable crops by 15-20% by increasing seed germination, improving root system development and increasing resistance to diseases. In the greenhouse experiment, the use of EM preparations increased tomato yields by 18% and cucumber yields by 21%, compared to the control group in which no biotechnology was applied.

The analysis of the obtained results confirmed the high efficiency of the model of a waste-free agricultural enterprise with the use of biotechnology. Production of EM preparations on the basis of waste, grain processing to produce protein feed additives and their use in livestock and crop production showed positive results. The obtained data are consistent with the results of other studies on the use of microorganisms in agriculture. The

use of Bacillus subtilis as a probiotic in the diet of calves showed an increase in average daily weight gain by 7%, and the use of EM preparations for the treatment of wheat seeds led to an increase in yield by 12%. The difference in our data compared to the above mentioned studies is probably due to the fact that our study used a more comprehensive approach with the use of several types of microorganisms and their combined action. It is also worth noting that the proposed model of a zero-waste enterprise has a number of advantages over traditional approaches to agriculture. It allows to reduce dependence on mineral fertilisers and chemical pesticides, reduce the amount of waste and increase the economic efficiency of agricultural production. In addition, the model promotes the creation of closed production cycles, which reduces the negative impact on the environment. However, it should be noted that the implementation of this model requires investment in equipment and staff training. In addition, biotechnological processes need to be adapted to specific production conditions to maximise efficiency. In general, the study has shown the promising potential of using biotechnology to create sustainable and highly efficient agricultural enterprises.

4 Conclusion

The conducted research allowed to develop and experimentally justify the model of a waste-free agricultural enterprise based on the application of biotechnology. The key element of this model is the use of effective microorganisms (EM preparations) for processing of agricultural waste and production of valuable products. It is experimentally shown that the fermenter used for the production of EM preparations provides biomass with sufficient titre, which guarantees the efficiency of further processes. The use of a variety of microbial strains adapted to specific cultivation conditions allows obtaining a stable and efficient biomass. During the study it was found that the addition of molasses to the nutrient medium increases the biomass yield, indicating that it is possible to use available and cheap waste for the production of EM preparations, reducing the cost of production.

Processing of grain raw materials to produce protein feed additives in low-power plants is another important link in the model. The data obtained indicate that it is possible to produce feed additives with a high content of crude protein and biologically active substances that increase the digestibility of feed by animals. The results of the experiment showed that the use of probiotisation and autolysis of grain can significantly improve the quality of forages and increase the efficiency of their use in animal husbandry. The use of these feed additives in the diet of farm animals and birds, showed an improvement in their productivity and health. In particular, an increase in the weight gain of young animals, milk yield of cows and egg production of chickens was observed, which emphasises the economic benefits of implementing the proposed technology. In addition, the use of EM preparations in crop production has also been shown to be effective. The use of these preparations for seed and soil treatment helped to increase crop yields by improving their development and disease resistance.

The proposed model of zero-waste agriculture is adapted to different types of agricultural enterprises. However, its full-scale implementation requires additional investment in equipment and staff training.

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