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ANALYSIS OF THE MAIN DESIGN AND OPERATING PARAMETERS OF THE DEVICE FOR THE FERMENTATION OF BIRD DROPPINGS

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Abstract

The study on the utilization of poultry droppings put forward the need for the constructive and technological improvement of the biofermentation device. A drum-type bioreactor better meets the requirements for the technological process of eco-friendly biologically active fertilizer production from livestock and poultry wastes. However, the great size of the heat transfer surface of the bioreactor drum and its significant ejection momentum during spinning require quite a lot of energy. To decrease this consumption, the main constructive parameters should be optimized. The main reason is the sharp increase in prices for mineral fertilizers, the weak economic condition of most farms, the lack of advanced processing technologies and the use of organic fertilizers.

Our aim in these studies was to analyze the types of design and operating parameters of the device for the fermentation of bird droppings. To this end, we conducted a study on the disposal of bird droppings, and also put forward the need for constructive and technological improvement of the biofermentation device. One of such ways to solve the problem was a drum-type bioreactor, which, according to our research indicators, better meets the requirements for the technological process of producing environmentally friendly biologically active fertilizers from animal husbandry and poultry waste, however, the size of this equipment of the heat transfer surface of the bioreactor drum and its significant emission pulse during rotation require a rather large waste of energy. To reduce this consumption, it is necessary to optimize the basic design parameters.

Devices that work continuously were recognized as the most promising. They fully meet the technological and operational requirements.

Keywords: poultry farm, utilization of poultry droppings, biofermentation, fertilizer, regime parameters, fermentation.

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1. Introduction

The droppings of any birds are a chemically very aggressive semi-liquid substance with an unpleasant odour and containing many dangerous microorganisms.

Cleaned or washed off litter can turn into a problem if it is not immediately processed into something necessary or useful.

The more birds there are, the faster the volume of their excrement will increase, in which pathogenic bacteria and eggs/larvae of worms that pose a threat not only to birds or livestock, but also to people [1]. Bird droppings cannot be used directly as fertilizer due to the presence of pathogenic microorganisms, viable helminth eggs and a large number of weed seeds in it. The introduction of such a litter without appropriate processing contributes to the removal of nutrients from the soil by weeds much more than is contained in the introduced bird droppings.

Analysis of existing technologies for processing poultry manure in Azerbaijan and abroad shows that there are various technologies, but most of them are associated with high costs, energy intensity and the need for special equipment, which is unacceptable for most farms with a weak economy [2]. The utilization of poultry droppings and developing economical and environmentally friendly machine techno-logy under nutritional deficiencies in agriculture is a very urgent issue.

Currently available numerous methods having model samples are considered to be sufficient for the choice of the effective technology for the utilization of poultry droppings [3].

Therefore, the research that is devoted to the justification of the operating parameters of the device for the fermentation of bird droppings has great scientific significance.

The paper Studies of specialists [3] indicate that the promising direction of the development of processing avian manure is the creation of low-waste or completely waste-free resource-saving production, which is based on the method of anaerobic fermentation of avian manure in bioreactors. The purpose of this work was mainly to analyze the process of the bioreactor operation during mixing of the fermented substrate in order to intensify heat exchange in the fermentation volume, since the performance of bioreactors depends on it. basically, the process of a vertical bioreactor with an anchor stirrer was analysed and it was found that the intensification heat exchange in the fermentation medium is possible by replacing free movement with its forced movement. They derived the equation of the heat exchange process operating under the forced movement of the fermentation medium in the boundary layer.

But they did not fully analyse the fermentation system of bird droppings, as well as the factors affecting the heat exchange process in fermented bird droppings.

In this study, [4] biogas production was analysed as a result of the joint digestion of pig manure, water hyacinth and bird droppings. Naturally, the use of pig manure in this case together with poultry for the production of biogas is also one of the ways to use poultry farm waste, but as in the first case, the authors set the goal of their work to obtain biogas by chemical means and specifically did not give efficiency when using poultry manure. Scientists have done [5] a lot of work to identify the reasons for the preservation of soil fertility. After the research work, they came to the conclusion that the best means to increase and preserve soil fertility, as well as increase the productivity of plants and animal litters, one of the main ones is bird droppings. But the authors do not present a specific methodology for the use of bird droppings. The authors in this article [6] mainly paid attention to environmental protection and one of the factors due to which this issue can be partially solved is the use of animal litters and one of their highly effective ones is bird droppings. The authors have carried out a lot of research work, the method of use, as well as resources, [7] has not been analysed. In this article, scientists analysed the waste of poultry farms, as well as the efficiency of using litter as an energy resource. The authors came to the conclusion that this unnecessary material is a valuable product. They analysed the scope of use and the effect of this product, but the method of using bird droppings was not specifically shown. The present [8] study is aimed at studying the use of poultry and household waste for the production of biogas. The current level of diesel fuel consumption is quite high, taking into account gas emissions and the rapid depletion of non-renewable fuel sources. The conducted research consists in adding a certain optimal amount of biogas from poultry waste to the gas mixture from the carburettor to reduce fuel consumption. In these studies, as in the previous ones, the authors mainly analyse the directions of using bird droppings, but do not give complete information about equipment and methods. In this [9] scientific work, the directions for improving technologies and technical means are analysed, the main reason for which is the need to create new technologies for the use of fertilizers due to the action of objective factors, But the authors do not specifically address this area and there is no critical analysis of existing technologies, which allows to conclude using the research methodology to find new ways to reduce costs and increase the quality of use of the proposed technologies. In this [9] article chiefly analyse about pH of wastage inoculated with Lactobacillus Plantarum and Streptococcus faecalis about fermentation isn't way improving of construction of equipment [10] show studies that analyse the development of a method for designing machine technologies for the disposal of manure, manure, taking into account production conditions and ensuring an increase in economic efficiency and environmental safety of livestock enterprises. The reason is that in many studies, the main attention in the study of technologies for the disposal of manure, manure was paid to the analysis of the influence of various factors on the fulfillment of sanitary, physico-chemical, agrotechnical requirements, productivity and economic efficiency of individual processes. At the same time, the assessment of technologies and machines by the level of environmental safety is fragmentary, practically there are no design methods and evaluation criteria for manure and manure disposal technologies that reduce the negative impact on the environment. Therefore, the development of a method for designing machine technologies for the disposal of manure, manure, adapted to the conditions of specific farms and ensuring increased efficiency and environmental safety of livestock enterprises is an important scientific, socio-economic and economic problem. As in many ongoing scientific studies [8] devoted to the development and improvement of design parameters for the use of bird droppings, the main focus is on the study of manure disposal technologies, productivity and economic efficiency of individual processes. While the main assessment of technologies and machines by the level of environmental safety, there are practically no design methods and criteria for evaluating manure technologies and manure disposal that would reduce the negative impact on the external environment. Therefore, the development of a method for designing machine technologies for the disposal of manure, manure adapted to the conditions of specific farms and ensuring increased efficiency and environmental safety is an important scientific, socio-economic problem. The information contained in patients are analyzed and compiled into seven groups.

This publication [8] mainly analyzes the process of converting bird droppings into fertilizers, feed, energy/fuel, and is also used for some non-traditional applications. In addition, methods for reducing odor/ammonia evaporation from poultry farm excrement and the development of microbial consortia for rapid decom-position of excrement are presented. And also shows their usefulness as a fertilizer. It is either used as the sole component of fertilizer, or used in combination with other plant and animal waste. The article highlights the technological details associated with this process, but this technique is not fully disclosed. This invention describes [11] a device for converting bird droppings into biological fertilizers and organic substrate. Yeast in the compositions of the invention has been stimulated to perform various functions, including the conversion of organic materials into non-hazardous plant nutrients. The invention also relates to methods for obtaining biological fertilizers and methods for using biological fertilizers to increase crop yields. This invention specifies the principle of operation and performance of this device, but there are no specific prerequisites and parameters for poultry farming.

As our research has shown, solving the problem of fermentation of poultry manure in poultry farms by substantiating the basic design and operating parameters is open and therefore we have made an attempt to analyze the shortcomings made by many authors and try to solve this problem.

The aim of the study is to substantiate energy-resource-saving, environmentally safe technology of poultry production and its technical solution.

In order to achieve the aim, the following objectives were defined:

– analyse the approach to machine technologies;

– it is necessary to develop a mathematical model of machine technology for the removal of bird droppings.

2. Materials and methods

A drum-type bioreactor better meets the requirements for the technological process of production of eco-friendly biologically active fertilizer from livestock and poultry wastes. However, the great size of the heat transfer surface of the bioreactor drum and its significant ejection momentum during spinning require quite a lot of energy. To decrease this consumption, the main constructive parameters should be optimized. One of the main parameters of the drum-type bioreactor is the ratio of its length to diameter (L/D).

The determination of the minimum heat transfer surface is possible using the equation expressing the dependence between the side surface and volume of the drum:

$$S_b = \frac{4V}{D} + \frac{\pi D^2}{2}, \tag{1}$$

where V – drum volume, m^3.

$$V = \frac{\pi D^2}{4} L, \tag{2}$$

D – drum diameter, m; L – drum length, m.

According to the equation, the minimum heat transfer surface can be acquired when $L/D=1$ and at the constant volume of the biofermentation chamber.

The energy is consumed mainly on the suppression of the ejection momentum during the drum rotation at a natural inclination angle. The rejection momentum can be calculated using **Fig. 1**.

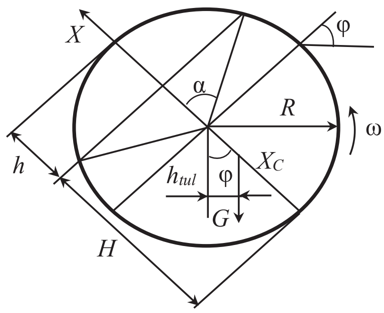

Fig. 1. Scheme for the determination of the rejection momentum

Rejection momentum is determined by the following formula:

$$M_{tul} = V_{qar} \rho_{qar} g h_{tul}, \tag{3}$$

where V_{qar} – volume of the mixture in the drum, m^3; ρ_{qar} – density of the mixture, kg/m^3; g – gravitational acceleration, m/sec^2; h_{tul} – ejector arm, the horizontal projection of the distance between the center of the drum and the composted mass, m.

The volume of the mixture in the drum is determined as follows:

$$V_{qar} = S_{en} L, \tag{4}$$

where S_{en} – cross-sectional surface area of the mass location, m^2.

Let's define the cross-sectional surface area of the mass location as follows:

$$S_{en} = R^2 \left(\pi - \alpha + \frac{\sin 2\alpha}{2} \right), \tag{5}$$

where R – drum radius, m; α – the angle of the circle sector, rad.

The center of the cross-sectional area of the mass location was calculated by the formula:

$$X_C = \frac{2R \sin 3\alpha}{3\left(\pi - \alpha + \frac{\sin 2\alpha}{2} \right)}. \tag{6}$$

Ejection momentum was found as follows:

$$M_{tul} = \frac{2}{3} R^3 L \rho_{qar} g \sin 3\alpha \sin \varphi, \tag{7}$$

where φ – natural inclination angle, rad.

The scheme for determining the loading percentage is shown in **Fig. 2**.

When loading 2/3 of the total volume, the cone volume is defined as follows:

$$V_k = \frac{1}{3}\pi R_0^2 h = \frac{0.012}{\text{tg}\varphi}\pi D^3, \tag{8}$$

where h – the height of the cone, $h = 0.33D$, m; $R_0 = h/\text{tg}\varphi$ – the radius of the cone base, m.

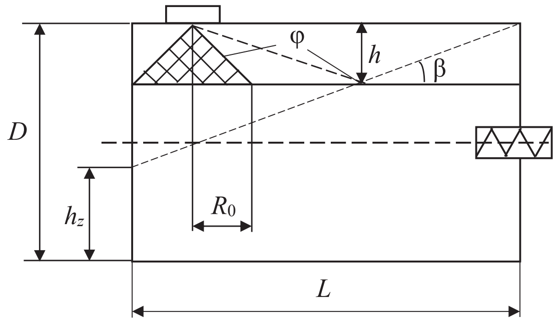

Fig. 2. Scheme for defining the loading plan

The volume of the mixture during rotation will be more than 1/3 of the drum volume. Because the fresh material is mixed with the content of the drum.

The displacing degree of the processed mixture by the fresh material is denoted as k_{six}. Given that the new mixture will be loaded during the $n_{yük}$ turn of the drum, it is possible to write the following:

$$V_{sut} = \frac{0.012}{\text{tg}\varphi}\pi D^3 n_{yük} = \frac{2}{3}\frac{\pi D^2}{4}\frac{1}{3}Lk_{six}. \tag{9}$$

After converting let's obtain:

$$L = \frac{0.216}{k_{six}\text{tg}\varphi}Dn_{yük}. \tag{10}$$

In this expression, only k_{six} is unknown. This coefficient is determined experimentally.

Worm transporter is used for extracting fertilizer. Considering the values of coefficients, the following formula was obtained for the fertilizer volume unloaded in one turn of the drum:

$$q_p = V_k = 5.18\pi d_1^3 t_{döv} n_p, \tag{11}$$

where d_1 – worm diameter, m; $t_{döv}$ – time spent for one turn of the worm, sec; n_p – rotation frequency of the worm, sec^{-1}.

Rotation frequency of the worm is determined by the following formula:

$$n_p = \frac{2.32D^3}{10^3 d_1^3 t_{döv}\text{tg}\varphi} = \frac{2.32}{10^3 k_p^3 t_{döv}\text{tg}\varphi}, \tag{12}$$

where $k_p = d_1/D$ – ratio of warm diameter to drum diameter.

3. Results and discussion

Formal and informal methods are used to make design decisions. Formal decision-making is a creative process, which is carried out on the basis of clear recommendations. These decisions are based on two main methods: optimization.

In optimization, the rules drawn up by highly qualified specialists are used. The rules determine what needs to be done in this or that event. Such rule for decision-making by less qualified performers.

There are two advantages of optimal decision making using electronic computing machine software: the first is a quick answer to the question, the second is an opportunity to conduct a large – scale experiment, which is often impossible to perform on a real object.

Despite the generality of the problem being solved, models of mathematical optimization developed on the supply of agricultural work with technical means, its composition and structure have a number of differences. All mathematical models can be conditionally divided into analytical and statistical options. In the first case, the main quantitative indicators of technological operations are associated with analytical dependencies. It is this system of equations that is considered an analytical model. When developing a statistical model (imitation model, Monte Carlo model), it taken into account that technological operations have a random element and it is not defined, but subject to the law of distribution of random quantities (a statistical model allows to study a system of any type).The possibility of taking into account nonlinearity, dynamism, probability nature of a number of events allows to make the statistical model adequate to the truth, to carry out the on a fast time scale by studying it.

Statistical models in the form of one-dimensional and multi-dimensional regression equations have found wide application in the research and optimization of parameters of agricultural machinery and aggregates and technological processes. However, if the specifics of agricultural work are not taken into account, the classical regression analysis leads to the presence of error of the model, even its unsteadiness, which makes its use impossible.

The problem of identification of the statistical model is that the data obtained in the passive or active experiment process will have an accurate AI ratio. Gauss proposed the least squares method as an algorithm for solving this problem.

Due to its simplicity and universality, the solution of issues with the realization of the linear programming method is more widespread. Linear dependencies are called, in which changes are formed only in the first degree, and there is no mathematical operation related to their product.

When using the linear programming method, the task posed is expressed by linear equations. The most common method of solving a problem with linear programming is the Simplex Method or the method of successively improving the plan. This method allows to solve any problem of linear programming with a limited number of steps (iteration). Each of these steps consists of algebraic turns according to the accepted rules. For solving linear programming problems, differential rent methods, potentials methods are also used. It is also possible to use the economic-mathematical model of the transport issue during the distribution of technical means by type of work. In a mathematical model, nonlinear programming is used in solving problems where variables are not of the first degree or are the product of variables. The most common among them is quadratic programming. This method is performed based on the maximum (minimum) of the quadratic function in the presence of linear constraints in solving economic-planning issues. One of the separate types of dynamic programming. This is applied when variables are considered in dynamics, and their solution is carried out in the form of the dependence of the goal function on change by time. In research on the mechanization of agricultural production processes, the issues of the analysis of dynamic systems occupy a significant place. Dynamic systems include all moving mechanical systems, technology and technical means, the process of development in space within a limited time interval and at the limits of coordinate indicators, automatic control of temperature and humidity regimes in greenhouses, livestock and poultry buildings. Sufficient work has been devoted to the issues of identification of dynamic systems.

The question of optimizing the composition, structure and use of the supply of agricultural production with technical means can be solved by applying the network model as a type of logical model. Research work [10], the network graph method for processing bird droppings and manure was successfully applied. One of the main tasks when conducting research on the mechanization of processes in agricultural production is to build an honest statistical model (to solve the identification problem), to study it and to optimize its application to specific criteria and production conditions. Various heuristic methods are used to solve the problem of identification in terms of application to dynamic systems, but as in the least squares method, a universal mathematical apparatus has not yet been developed. In practical reports, various algorithms and methods are applied that differ from each other.

However, all these issues have a common feature – they all belong to the class of search-related issues. For example, the search for the final amount of variables in hypersthene provided by users. For comparison of methods and analysis of their capabilities, work was carried out on identification of the reference model by various methods. As a result of comparative analysis, recommendations were developed to solve such issues. A systematic structural [8] model of automated design of technological processes in mechanical engineering was proposed.

The design process reflects multi-variant operations at all levels. As a result of the design, at all stages, a tree is formed that can meet the technical constraints imposed by the allowable variants of the technological process (TP). At the final stage, the multi-level TP model with the optimal solution option selection is described in **Fig. 3**.

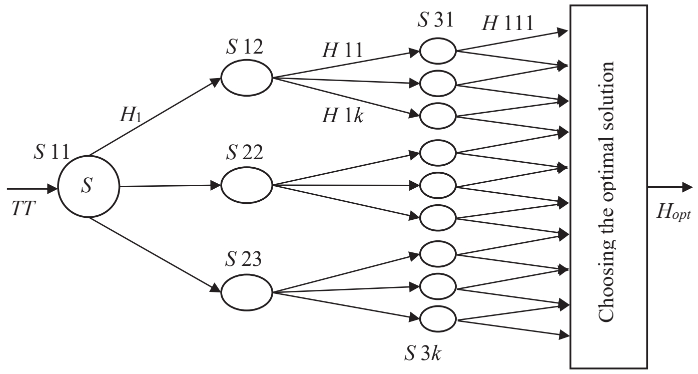

Fig. 3. Multi-level technological process model, choosing the optimal solution at the final level: *TT* – technical task; *S* – synthesis of project solution options; *H* – solution options

The synthesis (*S*) operations of the project solution options per tree, and to the bends the obtained variants of these solutions (*H*) are suitable. At the final level, the bends of the tree characterize the draft variants of the given degree of felt.

The entire multi-level design process can be imagined as a sequence of different levels and operations to select the optimal variant (Q) according to the criteria given at the final level.

The design model we are looking at is characterized by low efficiency. In order to choose a rational option, it is necessary to design a large number of technical limited options that can be left to the end. The effectiveness of the process can increase dramatically if at each level the choice of a rational project solution is organized. At this time, the intermediate selection criteria are $Q_1, Q_2, ..., Q_H$. The problem (the most rational variants at different levels) is faced. Apart from the latter, it is not possible to have a precise assessment and selection criteria for project solution options at all levels, as project solution has different perceptual levels. Thus, at the first level, it is impossible to formulate a criterion that allows to choose one optimal variant of the principled scheme of the technological process. This is due to the fact that the idea of the process being designed here is of a principled nature and is felt and clarified at subsequent levels. Therefore, apart from the latter, the criterion for evaluating a project solution at all levels of design, to one degree or another, is heuristic in nature. These have been achieved on the basis of experience in solving similar issues.

In connection with the nature of the criterion for choosing the most rational solution option, the task of a multi-level system of automated design is fulfilled in such a way that at each intermediate level of design, not only one best option is selected, but also several close to it options. At the last stage, the final version of the price of a complex criterion of quality is chosen, the largest or smallest in comparison with other prices. A multi-level process model with a defective selection at all levels of technological development **Fig. 4** – also described.

A multilevel process model with a defective selection of all levels is characterized by high efficiency. Thus, at each stage of the design, the user has the opportunity to choose several options that are close to the best option. At the final stage of designing, a final option is selected. According to the user's opinion, this corresponds to the quality criterion.

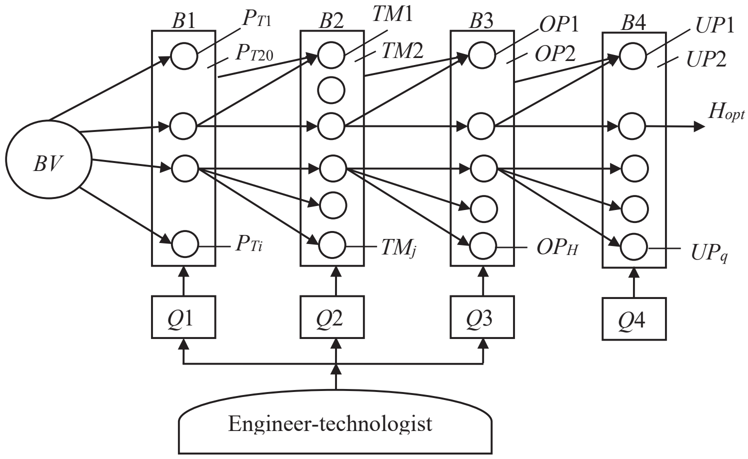

Fig. 4. Multi-level process model of technological design with defective solution selection at all levels: BV – initial data for the design of technologies; P_{Ti} – technological options; TM_j – options for the implementation of technological operations; PH – technical means for the implementation of operations; UP_q – the results of the obtained technologies; selection blocks for the most rational solution on the criteria $B1$-$B4$-$Q1$-$Q4$; H_{opt} – analysis of options by selecting the optimal solution

Presented methodology, algorithms, software packages in his scientific work «automated design of machine technology of potato production». If the properties of objects are interchangeable, any technology and any technological process can be implemented. The joint use of objects of such properties ensures the implementation of techno logical processes.

The design process includes the following successive steps: studying the technology designed farm; collecting and evaluating the initial data on production conditions; comparing the initial data with the technology limiting the application of technology according to the base data contained in the electronic computing machine program; making a decision on the possibility of machine technology for the given farm conditions.

The algorithm for choosing a rational variant of the technological process is applied in the form of implication. Based on the principle of research, several technological options are formulated from rational technological processes.

The development of a method for designing bird droppings disposal technology is a complex, multi-faceted task.

One of the main tasks of experimental research was to verify the adequacy of the developed mathematical models of heat and mass transfer in heat exchanger channels. To do this, the experimental values are compared with the theoretical values obtained on mathematical models at the test stage. The comparison was made on the basis of objective values of temperature and humidity at the entrance and exit from the refrigerator and other indicators. A method was used to determine the relative error of theoretical values in comparison with experimental values.

The magnitude of the relative error is determined by the following formula:

$$g = \left| \frac{\sum g_i}{S_i} \right| \cdot \frac{100\,\%}{n_{nöq}}, \tag{13}$$

where g – relative error; g_i – i is absolute value of the deviation of the experimental point from the angle to the average; S_i – i is the price of the experimental quantity at the point; $n_{nöq}$ – quantity of investigated pair of points.

Known elements of probability theory and mathematical statistics were used to process prices obtained empirically. When making measurements, it is believed that they are made with constant accuracy and important errors are distributed under normal law. The difference between average reporting prices and experimental results when determining the authenticity of received prices was analyzed according to the following methods.

Taking into account the multiplicity of the obtained measurement results, the average numerical value is found as follows:

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}, \tag{14}$$

where X_i – the result of each i-measurement in the course of an experiment; n – number of observations in the course of an experiment.

In practice, the deviation of the average numerical value for each observation is determined by the following formula:

$$\Delta X = X_i - \bar{X}. \tag{15}$$

After that, the average quadratic tendency in practice is calculated:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} X_i^2}{n-1}}. \tag{16}$$

Margin error is calculated as follows:

$$\Delta \lim = \pm 3\sigma. \tag{17}$$

After that, all experimental values beyond this interval $\left(\bar{X} \pm 3\sigma\right)$ were considered to be false and the experiment was repeated.

The error of each experiment is defined as:

$$\Delta\sigma = \frac{\sigma}{\sqrt{n}}. \tag{18}$$

The reliability interval is as follows:

$$E = t(n)\Delta\sigma, \tag{19}$$

where $i(n)$ – the Styudent criterion is the price, it is taken from the table and is based on the number and ethimal reliability of the experiment.

As is known, the amount of measurements (observations) during the course of an experiment is determined not only by measurement methods, but also by the required reliability of the final result and the average quadratic inclination.

Margin error of measurement in the experiments recorded for objective evaluation 98 % reliability level 3σ amps were adopted. In this regard, the number of observations 5 was taken in order to get one experimental estimate of the studied quantity in the course of one experiment.

During the formation and selection technology, it is most expedient to base on the condition of biological turnover of nutrients in bird extracts, normalization of its composition, activation of soil microflora, nutrition of agricultural plants playing an active role in external influences system.

External influences include economic conditions, applied technologies consisting of processes and operations, technical means performing operations. For the formation of any technology, the following considerations must be adopted:

– at all stages of impact, the same product – bird excrement is involved as a subject of labor. Their physical-mechanical, microbiological, agrochemical and sanitary – hygienic properties are purposefully changed in the direction of the latest indicators required by the soil;

– the starting state of the excrement being the subject of labour has the same status vector for all types of organic fertilizers, which is determined by the specialization of the enterprise, as well as the excrement removal system;

– the type of organic fertilizer obtained in the process of processing additives is determined by agro-chemical, physical-mechanical, sanitary-hygienic and other requirements of plants, as well as by the microflora of the soil, environmental requirements of the environment. Under the influence of operations, technological and technical means, the beginning zig turns into organic fertilizer. To describe such a system in the form of an information model, a structural-parametric scheme of the operation of the technology can be used (**Fig. 5**).

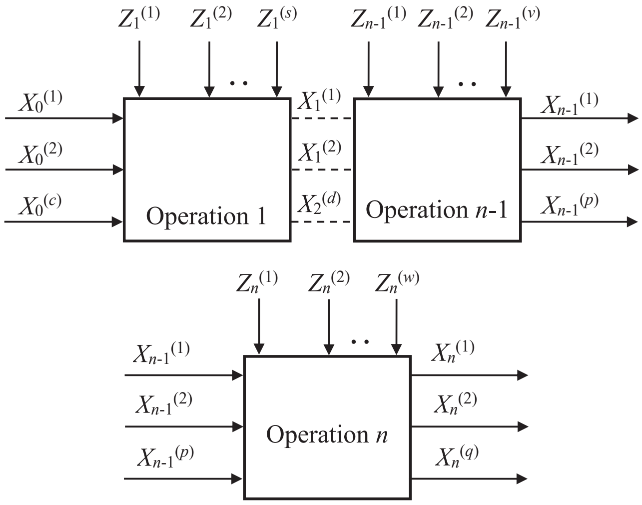

Fig. 5. Block diagram of a multidimensional, multi-stage technological process

Suppose that the process under study consists of N multi-dimensional operations. The input of the process is influenced by random quantities, and the output of the first process has a random quantity, which forms the input for the other process. The output of the entire technological process is characterized by random quantities. The quality of the finished organic fertilizer is affected not only by the parameters of the starting material, but also by the parameters of technical means. In each operation, etc. random factors influence.

The multilevel model of technological design prose with the removal of defective results at each level is characterized by high efficiency. Here it is possible to choose several options that are closer to the best. At the final stage of designing, a final option is selected. This option, in the opinion of the user, is based on its competence and meets the quality criteria.

The design process combines the following consistently implemented steps:

– application of technology selected farm;

– collection and classification of information on production conditions;

– comparison of collected data with the application of technology in terms of limitations in the database of electronic computing machine;

– dropping disposal technology and formalization of its variants taking into account economic conditions;

– decision-making on the possibility of technology selection according to its output parameters for given economic conditions.

The algorithm for choosing a rational variant of technological processes is compiled in the form of implication.

In the description of the system of utilization of zig with the purchase of organic fertilizers, we are guided by the fact that the study of the technology can be presented as a two-point task. It is built as follows: it is required to bring the system from any starting State (X_0) to the final state (X_T) in the T-Time interval.

The information model of the factors influencing the protection of nitrogen in the zig disposal process is presented in **Fig. 6**.

Thus, the rotation frequency of the unloading worm depends on the rotation frequency of the drum and natural inclination angle of fertilizer at the established working regime of the bioreactor.

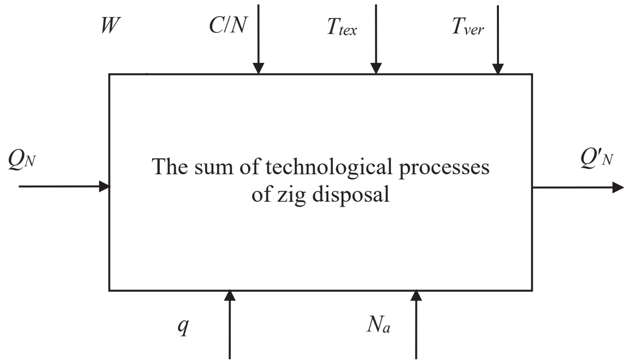

Fig. 6. Information model of factors affecting nitrogen protection:
Q'_N – the amount of N (nitrogen) delivered to the plant; q_n – the amount of N in the fresh sludge; W – zigh moisture; C/N – the ratio of azotes to carbon in the initial sludge; T_{tex} – technology intensity (processing time, temperature regime, quantity of technological operations); T_{ver} – technology of fertilizing (time passed from fertilizing to spraying); q – quality of technological operations; N_a – climatic conditions

A layer of the prepared fertilizer should always be on the fertilizer unloading worm for providing its continuous, sustainable functioning. Moreover, for increasing the volume of each time loaded material, it is necessary to decrease the height of the processed material near the loading hatch. The worm inclination towards the manure unloading side can solve this problem (**Fig. 7**).

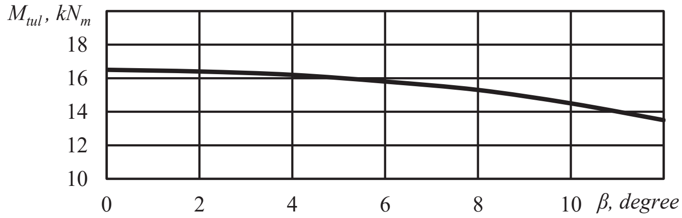

Fig. 7. Dependence between ejection momentum (M_{tul}) and inclination angle (β) of the drum

The limitation for the drum inclination is the height ($h_k = D$) of the finished fertilizer near the side wall of the drum. This ensures normal aeration and mixing mode.

When filling the drum up to 2/3 part, the drum limiting inclination angle is defined by the following formula:

$$\beta = \mathrm{arctg}\left(\frac{1.33}{k_b}\right), \qquad (20)$$

where k_b – ratio of the length of the drum to the radius, $k_b = L/R$.

The inclination of the drum effects on ejection momentum (**Fig. 5**).

Ejection momentum related to inclination angle was integrating throughout the drum:

$$M_{tul} = \frac{2}{3} R^2 \gamma g \sin\varphi \int_0^{k_b R} \sin^3\left[\arccos\left(\frac{h_2 + y\,\mathrm{tg}\beta}{R}\right)\right] \mathrm{d}y. \qquad (21)$$

The graph presented in **Fig. 4**, was constructed by the Math CAD. The calculation was performed for the drum with a unit radius and a ratio of $k_b = 6$. As seen in the figure, ejection momentum declines with the increasing inclination angle of the drum. The obtained results can be used also for other types of drums.

Thus, the ratio of the bioreactor drum length to its radius is dependent on the followings: the degree of the displacement of the mixture in the bioreactor by newly loaded fresh mixture; natural inclination degree and volume of the newly loaded fresh mixture. The drum inclination in the opposite state ensures an 18 % decrease in ejection momentum and an increase in the one-time loading share.

The analysis of the main parameters of the biofermentation process and methods of the determination of them show that the shortcomings were eliminated in the following directions:

– acceleration of the biochemical processes of the substrate oxidation using biological catalysts-enzymes;

– intensifying the mass transfer between microflora, substrate, and oxygen by increasing the substrate grinding and increasing its porosity;

– equalization of the temperature field along the cross-section of the composted mass by strengthening the heat insulation;

– acceleration of the loading-unloading processes and reducing NPK loss by additional processing.

A system of differential equations that describes the process of air, heat, and moisture transport at the same time during exothermic processes, in the pool of organic substances, is as follows:

$$\frac{\partial t}{\partial \tau}=\frac{\partial}{\partial x}\left(a_1\frac{\partial t}{\partial x}\right)+\frac{\nu_H C_H \rho_H}{C_{qur}\rho_{qar}}\frac{\partial t}{\partial \tau}+\frac{\varepsilon C_{bux}}{C_{qar}}\frac{\partial W}{\partial \tau}+\frac{\omega}{C_{qar}\rho_{qar}}, \tag{22}$$

$$\frac{\partial W}{\partial \tau}=\frac{\partial}{\partial x}\left(\alpha_m\frac{\partial W}{\partial x}+\alpha_m\delta\frac{\partial t}{\partial x}\right), \tag{23}$$

$$\frac{\partial C_0}{\partial \tau}=k_p m\frac{\partial^2 C_0}{\partial x^2}-U_H\frac{\partial C_0}{\partial x}-k_p C_0 F_{ef}, \tag{24}$$

where α_t, α_m – coefficients of heat and humidity transfer; C_{qar} – specific heat capacity of the mixture, J/kg°C; ρ_{qar} – density of the mixture, kg/m^3; U_H – air transfer rate to the pool of poultry droppings, m/sec; m – porosity of the mixture, %; k_H – coefficient of air penetration; C_H – specific heat capacity of the air, J/kg°C; ε – coefficient of water vaporization; C_{bux} – heat of vaporization, J; ρ_H – air density, kg/m^3; ω – specific heat flow of the decomposition reaction; C_0 – oxygen concentration in air at the point x; k_p – speed constants of the decomposition reaction; F_{ef} – effective surface of air pores, m^2.

In exothermic processes, the heat loss to the environment will be proportional to the temperature gradient on the surface of the pool of bird droppings:

$$\alpha_1\left(t_s-t_{em}\right)=\lambda\frac{\partial t}{\partial x}, \tag{25}$$

where α_1 – coefficient of heat conversion of mixture; t_{em} – ambient temperature, °C; t_s – surface temperature of the pool of poultry droppings, °C; λ – heat transfer coefficient, W/m°C.

Solution (25) of the equation system (22)–(24) under the exceptional conditions, when the current coordinates of the mixture pool are x, y, z, the mixture humidity is W_{qar}, air concentration is C_0, and time is τ can be written as follows:

$$t=f\left(x;y;z;W_{qar};C_0;\tau\right). \tag{26}$$

Solving this function by the analytical method is quite an issue. The solution to the problem can be facilitated by performing the practical work (deforming, decontamination, destruction of weed seeds, enzyme collection, etc.) at dynamic equilibrium in the stationary mode.

Then the heat balance equation is used to solve the solution of the system (22)–(24):

$$N_{qar}=N_{is}+N_H+N_{Bux}, \tag{27}$$

where N_{qar} – heat flow from the decomposition of organic substances, J; N_H – heat spent on the aeration, J; N_{Bux} – heat spent on the vaporization, J.

Taking into account the symmetry of the cross-section of the composted mass, it is better to study the process of heat exchange with the environment in an r dimensional coordinate system. Analysing the cross-section of the composted mass, let's define the individual elements and obtain the full expression of the heat balance:

$$S_{en}\rho_{qar}q_{qar} = S_{em}\lambda\frac{\Delta T}{\Delta X} + S_{en}\rho_{qar}C_H\Delta T_H k_H + S_{en}\rho_{qar}C_{bux}k_W, \tag{28}$$

where S_{en} – the cross-section of the calculated element of the composted mass, m^2; S_{em} – heat exchange area of the mass with the environment, m^2; q_{qar} – specific heat dissipation of the composted material, J/m^2; ΔT – difference between the center of the composted mass and the outside air temperature, °C; ΔT_H – difference between incoming and outgoing air temperatures, °C; k_H – specific air consumption; ΔX – elementary thickness of temperature dispersion sphere, m.

Thus let's obtain:

$$\frac{\Delta T}{\Delta X} = \frac{S_{en}\rho_{qar}}{S_{em}2\lambda}\left(q_{qar} - C_H\Delta T_H k_H - C_{bux}k_W\right). \tag{29}$$

Let's use the following designations:

$$\frac{S_{en}}{S_{em}} = r\frac{f_{en}}{f_{em}} = rf_{for}, \tag{30}$$

$$q_{qar} - C_H\Delta T_H k_H - C_{bux}k_W = q_a, \tag{31}$$

$$S_{en} = r^2 f_{en}, \tag{32}$$

$$S_{em} = rf_{for}, \tag{33}$$

where r – characteristic size of the composted mass; q_a – active temperature of biometric processes, J; f_{en} – coefficient for the cross-section of the composted mass; f_{em} – coefficient for the surface of the composted mass contacting with the environment; f_{for} – coefficient for the respective form of the composted mass.

Coefficients for the respective forms of the composted mass are presented in **Table 1**.

Table 1
Coefficients for respective forms

Cross-section of the composted mass	f_{en}	f_{em}	f_{for}
Triangular	1	2/cosα	cosα/2
Semi-circular	π/2	π	1/2
Circular	π	2π	1/2
Rectangular	$2k_h$	$2(2+k_h)$	$k_h/(2+k_h)$

Then, the heat balance equation is as follows:

$$\frac{\Delta T}{\Delta X} = \frac{rf_{for}\rho_{qar}}{\lambda}q_a. \tag{34}$$

Let's integrate the expression for the determination of the temperature differences in the centre of the composted mass and its surface:

$$T_{mer} - T_0 = \int_0^r \frac{rf_{for}\rho_{qar}}{2\lambda}q_a \mathrm{d}x - \frac{r^2 f_{for}\rho_{qar}}{4\lambda}q_a, \tag{35}$$

where T_{mer} – temperature in the center of the composted mass, °C; T_0 – temperature on the surface of the mass, °C.

The temperature at any point is determined by the following expression:

$$T_r = t_0 \frac{\left(r^2 - x^2\right) f_{for} \rho_{qar}}{2\lambda} q_a. \tag{36}$$

The temperature within the mass varies according to the parabolic law and depends on the external temperature. In this case, the outer layers play a role of the simple thermal insulator.

It is coated with a heat-insulating layer to reduce losses and create a more uniform temperature range in the mass.

The heat flux passing through the insulating layer is determined by the following formula:

$$N_{AX} = r f_{em} \alpha_T \left(t_{AX} - t_{xar}\right), \tag{37}$$

where α_T – coefficient of heat transfer of thermal insulation layer; t_{xar} – external air temperature, °C.

The amount of heat generated in the composted mass per unit of time is as follows:

$$N_{AX} = r^2 f_{en} \rho_{qar} q_a. \tag{38}$$

Equalizing formulas (37) and (38) it is possible to find the temperature of the top layer of the compost:

$$t_0 = t_{xar} + \frac{r f_0 \rho_{qar}}{\alpha_T} q_a. \tag{39}$$

Then, let's find the minimum radius of the mass that provides the required temperature of the compost:

$$r_{\min} = \frac{\alpha_T \left(t_{\Delta x} - t_{xar}\right)}{f_{for} \rho_{qar} q_a}. \tag{40}$$

Using (39) in (35) it is found the formula determining the temperature in the center of the compost:

$$T_{mer} = t_{xar} + \left(\frac{r^2}{4\lambda} + \frac{r}{\alpha_T}\right) f_{for} \rho_{qar} q_a. \tag{41}$$

The temperature at any point can be determined by the following formula:

$$T_{mer} = t_{xar} + \left(\frac{r^2 - x^2}{4\lambda} + \frac{r}{\alpha_T}\right) f_{for} \rho_{qar} q_a. \tag{42}$$

The basis for the production of organic fertilizers is bird droppings. In the process of their movement from animal to plant, random and purposeful changes occur. Both physical weight and qualitative indicators are subject to this change. Hence, it is concluded that the correct developed mathematical model will increase the efficiency of the developed device.

As it was analyzed above, the main problem facing poultry farms is to increase productivity, with the use of modern technologies, one of which is the lighting system, the climate in the poultry house and the use of bird droppings. The main limitation in this study was the lighting system replacing the conventional lighting system with ultra violet bactericidal lamps with protective glasses. UV germicidal lamps with a protective glass coating are the most effective means of both lighting and dehumidification in poultry houses. They exclude radiation at a wavelength of 184.9 nm. The ozone capacity of these lamps is 4.5 mg/kWh. There are also special lamps with quartz glass, in this regard, the main direction of our research will be to solve this problem or find a way that could replace these lamps, that is, conducting additional research with special lamps with quartz glass.

4. Conclusions

The obtained research data show that it is more expedient to rely on the indicators of total energy consumption to assess the energy efficiency of the production process at a poultry enterprise. At the same time, it is necessary to determine the air humidity, temperature and all air components in the poultry holding area, as well as in the buffer zone, using the equations included in the methodology developed to justify the ventilation option of the poultry house with control parameters and external conditions.

A comparative assessment of the declared and actual prices for nitrogen conservation in poultry farms, the technology of processing poultry manure showed the high adequacy of the developed model.

Thus, the accumulated knowledge about the compliance of the processing process of poultry manure, the developed methodology and models are able to determine the level of nitrogen preservation, allow to evaluate the technology of manure disposal from an economic and environmental point of view. The use of an existing set of moisturizing equipment has shown that they often fail. Upon destruction, a salt layer is formed on the rotating disk. The results obtained allow to determine the direction of improvement of the humidifier.

A more rational way of normalizing the temperature and humidity parameters of the air environment based on the sub-evaporative principle of plate coolers in the local climatic conditions of the country in the summer season has been developed.

Based on the mathematical model, the methods of computer studies have been developed to increase energy efficiency of Poultry Building. With the help of a computer program, a light for a bird building with dimensions 66×12 m amount of LEDs ($\alpha = 200$, $i_0 = 20$ kd) amount of $N = 273$ piece, a light for a building with dimensions 78×18 m amount of LEDs ($\alpha = 200$, $i_0 = 20$ kd) amount of $N = 259$ piece, constructive parameters of luminaires are substantiated.

Conflict of interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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