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Evaluation of a plant for the preparation of liquid feed mixtures from the bioenergy side

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Abstract. The main task of energy analysis in the broad sense of the word is to study, quantify, optimize energy flows and manage them in agricultural systems and animal husbandry in order to create such farming methods that would ensure: the maximum use of biological means of production of natural resources, substances and energy to achieve a constant and sustainable increase in the productivity of agricultural production and animal husbandry; environmental protection from destruction and pollution, preservation of water, air and food quality within the limits safe for human health (that is, the creation of a favorable environmental environment).The article discusses the assessment of the efficiency of an installation for the preparation of liquid feed mixtures for various types of animals. A method of bioenergy efficiency as an efficiency factor is proposed.

1 Introduction

The main task of energy analysis in the broad sense of the word is the study, quantification, optimization and management of energy flows in agricultural systems and livestock farming in order to create farming methods that would ensure:

- maximum use of natural resources, substances and energy by biological means of production to achieve constant and sustainable growth in agricultural and livestock productivity;
- protection of the environment from destruction and pollution, maintaining the quality of water, air and food within limits safe for human health (that is, creating a favorable environmental environment).

One of the tasks is the development of resource-energy-saving technologies for the production of food raw materials and feed and their mass development.

When obtaining food resources and feed, various types of raw materials and supplies, machinery and equipment, buildings and structures, and so on are used. All this is characterized by a certain energy capacity, expressed by the energy costs for their production, transportation, maintenance, repair, storage, and so on. The total specific energy consumption of the technology (process) under consideration is determined by summing up the energy consumption for each technological operation.

The livestock farm, as an energy system, is a large energy consumer. The principle of energy approaches is applicable to it, as to any other system. Therefore, when choosing a

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system of mechanization, electrification and automation in livestock farming, with subsequent assessment of the results of the farm as a whole, it is possible to use energy indicators [1,2,3].

Energy analysis is an additional method for justifying and selecting energy-saving technologies. It allows you to assess the efficiency of the functioning of livestock industries, substantiates the feasibility or inexpediency of using individual measures or techniques in production [4,5,6].

Any technology, be it raising animals or obtaining final products at known costs in real terms (kg of fuel, fertilizers, etc.) must be determined on the basis of the energy equivalents of each type of cost.

Energy equivalent is a value obtained by summing up the energy resources used at each stage of production, storage, transportation of a unit of each type of material input (kg of fertilizers, building materials, etc.). This takes into account energy costs for the production of fertilizers, equipment, building structures, energy carriers (coal, gas, gasoline, diesel fuel) and much more.

It is proposed to evaluate the energy intensity of product production by the ratio of the total costs at all levels of the economy to the energy content of the final product, that is, to the energy contained in the product.

Figure 1 roughly shows the energy balance on the farm and energy flows. Any arrow (Figure 1) represents material flows of various types, but each of them is accompanied by a flow of energy that converges into one node and thus interacts with each other in the process of food production. If each flow is expressed in its own units of measurement, for example, the supply of nutrients in centners, energy from an external source (solar) in kJ, the flow of money in rubles, the flow of food products in kilograms or tons, and so on, then evaluate all these flows will be difficult. However, if all these material flows are expressed in the same units of measurement (for example, in kJ), then the flows will be comparable. Then the sum of the flows at the "input" should be equal to the sum of the flows at the "output" (in the ideal case or taking into account losses).

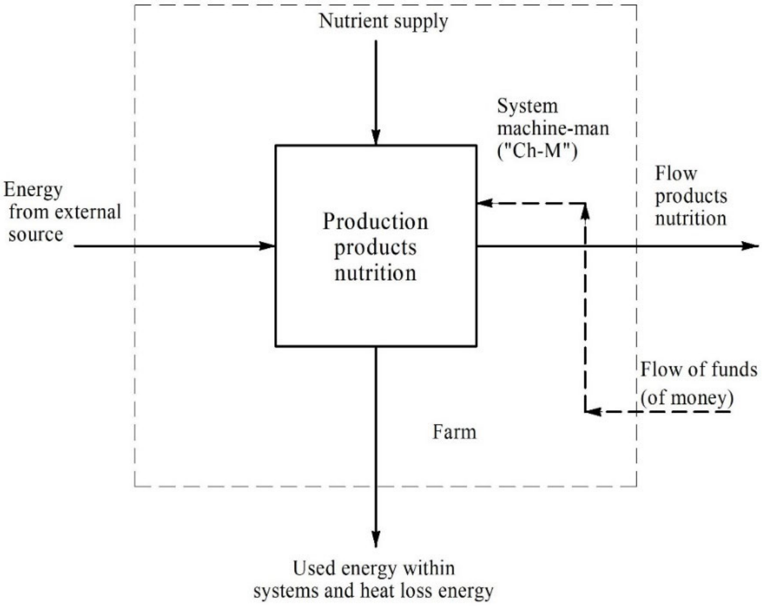

Fig. 1. Conditional diagram of energy flows on the farm.

Considering the farm as a large object of energy consumption and its reproduction in food products, one can see and be convinced: in what parts of the technology of energy consumption and its reproduction can one obtain an economic effect, that is, increase the bioenergy efficiency factor (efficiency factor).

In recent years, much attention has been paid to energy analysis of existing and promising machine technologies. Such an analysis serves as an additional method for selecting and justifying energy-saving technologies, reveals the low efficiency of the energy functioning of some agricultural sectors, and indicates the advisability of using measures and techniques in food production. The method for assessing the energy intensity of final types of agricultural products necessary for human nutrition has been widely developed.

This takes into account energy costs for the production of fertilizers, equipment, building structures, and energy resources (coal, gas, diesel fuel, gasoline).

The energy intensity of product production is usually assessed by the ratio of the total energy costs in all parts of the economy to the energy content of the final product (that is, to the energy contained in the product).

Energy analysis gives an idea of energy costs as one of the physical categories required for a given production.

Energy costs in agriculture are divided into direct and indirect. By direct, easily calculated, we mean costs directly related to the execution of work. These include the consumption of liquid energy carriers (gasoline, diesel fuel) by tractors, cars, stationary machines, etc., as well as the consumption of electrical energy to drive machines, the consumption of coal, gas, peat, firewood, and so on.

Indirect costs (materialized) include energy costs for the manufacture, storage, transportation of machines and tools, chemical agents, construction materials for buildings, farms, warehouses, and so on. Indirect energy costs also include energy spent on production, processing and transportation of the consumers themselves: oil, gas, coal and so on.

The energy intensity of animal rearing technologies at known costs in real terms (kilograms of fuel, feed, etc.) is determined on the basis of the energy equivalents of each type of cost.

The energy equivalent of direct costs consists of the sum of two parts: calorie content (that is, the energy released during the combustion of a unit of mass or volume of energy carrier.

Social development requires every possible saving of labor, material, fuel, energy and financial resources.

2 Methods

All saving ultimately comes down to saving time, for the first economic law in collective production is the general law of saving time. Saving working time is associated with an increase in energy availability and energy consumption; at the present time, the growth of food production is largely associated with an increase in energy availability and an increase in fuel and energy consumption. In this regard, farms are becoming one of the largest energy consumers. The dynamics of changes in total energy consumption in developed countries shows that the difference in energy consumption and its reproduction in food products is constantly growing, and the bioenergy efficiency factor (COP) is falling.

The bioenergy efficiency factor (efficiency) is determined by the formula:

$$\eta_B = \frac{E_{exit}}{E_{enter}}, \tag{1}$$

where E_{exit} is the energy contained in the products produced (grain, straw, milk, meat, etc.), MJ;

E_{enter} – energy flow at the input (energy costs for buildings, machines, electricity, etc.), MJ.

In practice, an increase in E_{exit} is achieved through direct saturation of technological processes with energy flows, which leads to a decrease in bioenergy efficiency (B).

It is easy to see that at $E_{enter}\to 0$ we have $E_{exit}\to E_0$, where E_0 is the naturally obtained energy (MJ), that is, the energy of the products tends to the naturally obtained energy (the primitive method, when they did not look after the cow, but only took her milk).

At a very high value of $E_{enter}\to\infty$ we obtain $E_{exit}\to K$ where K is the limit for the growth of energy output and food products (yield, milk yield, etc.).

For different farms, for different farms and processes, the value of bioenergy efficiency (B) may be different. In calculations of various mechanization options (with a constant value of other values for other processes), you can use this technique (at least as a recommendation, verification or approximate).

Such a calculation is suitable for determining the effectiveness of a particular option for any process (or machine, or technology), in particular, when other indicators for the processes are fixed at constant levels. In real conditions of equipment operation, with complex mechanization of all processes, it is necessary to calculate options for all indicators (including buildings, structures, fertilizers, feed and everything else for a specific technology).

We will make calculations based on the need for a whole milk substitute for young animals. Table 1 shows the need for a substitute for various types of animals in summer and winter.

Table 1. Demand for whole milk replacer for various animal species, for winter and summer periods.

Species of animals and birds	**Period**	
	winter	**summer**
Heifers over 2 years old	4.80	4.0
Gobies: - over 2 years old - up to 1 year	 0.04 0.05	 0.04 0.05
Boars producers	0.40	0.60
Sows	0.35	0.50
Piglets: - soaps - weaners	0.03 0.35	0.03 0.15
Fattening livestock of pigs	0.60	0.30
Replacement young growth	0.60	0.50
Ewes	0.14	0.06

For comparative characteristics, we will select the SV-10, P-8-ORD-M mixer, which we will compare with the pilot plant according to patent No. 146974. We present the technical characteristics in Table 2.

Table 2. Technical characteristics of the serial installation and prototype.

Indicators	**Designation**	**Numerical values of variants**		
		SV-10	**P-8-ORD-M**	**pilot plant**
Weight, kg	G	260	55	50
Throughput, t / h	Q	10	15	8
Installed power, kW	ΣP	18.5	5.5	2.2
Service staff, people	L	1	1	1
Daily operating time, h	$T_{m(day)}$	6	6	6

The daily consumption of each type of feed is determined per head for the sex and age group of animals using the formula:

$$Q_{daily} = q_i \cdot m_j, \tag{2}$$

where q_i is the amount of daily intake of the i-th feed, kg;
m_j – number of animals on the farm of the j-th group, goals.

The farm's annual need for feed of each type is determined by the formula:

$$Q_g = Q_{day.l} \cdot T_l \cdot k + Q_{day.z} \cdot T_z \cdot k, \tag{3}$$

where $Q_{day.l}$ and $Q_{day.z}$ – daily feed consumption in the summer and winter periods of the year, kg;
k – coefficient taking into account feed losses during storage and transportation, k=1.01 – for concentrated feed;
T_l and T_z – duration of summer and winter use of this type of feed, T_l=155 days and T_z=210 days.

The energy content of the entire resulting liquid feed is determined by the formula:

$$E_{exit} = Q_g \cdot E_{em}, \tag{4}$$

where E_{em} is the energy equivalent, E^{em}=2.7 MJ/kg.

The total input energy (energy flow at the input) is determined by the formula:

$$E_{enter} = E_{enter(tr.res)} + E_{enter(plant)} + E_{enter(power)}, \tag{5}$$

where $E_{enter(tr.res)}$ is the energy content of human labor costs, MJ;

$$E_{enter(tr.res)} = V_{god} \cdot E_{e(tr.res)}; \tag{6}$$

$$V_{god} = T_{m(day)} \cdot T_g \cdot L, \tag{7}$$

where V_{god} – annual labor costs, people. h;
$T_{m(day)}$ – machine operating time during the day, h;
T_g – number of days of machine operation during the year, Tg=365 days;
L – number of service personnel, people.

The energy content of human resource costs is determined by the formula:

$$E_{enter(tr.res)} = V_{god} \cdot E_{e(tr.res)},, \tag{8}$$

where $E_{e(tr.res)}$ is the energy equivalent of 1 person-hour of service personnel, $E_{e(tr.res)}$=41.3 MJ/h.

The energy intensity of the equipment is determined by the formula

$$E_{god.power} = T_{m(day)} \cdot T_g \cdot P_{total}, \tag{9}$$

where P_{total} is the total installed power of equipment (machines), kW;

$$P_{total} = P_m \cdot P, \tag{10}$$

where P_M is the number of machines for a given technological operation, pcs.;
P – installed drive power of the working parts of a single machine, kW.

The energy content of consumed electricity per installation is determined by the formula:

$$E_{enter(power)} = E_{g.power} \cdot E_{e(power)}, \tag{11}$$

where $E_{e(power)}$ is the energy equivalent of 1 kWh. electrical energy; $E_{e(el.e)}$=8.7 MJ/kWh.

3 Results and discussion

Let's carry out the calculations in this order. For each animal species we will select a population in order to realistically assess changes in the bioenergy coefficient. To do this, we will create Table 3, in which we will display all the data received.

Table 3. Calculation results.

Species of animals and birds	**Livestock. heads**	**Bioenergy coefficient**		
		SV-10	**P-8-ORD-M**	**pilot plant**
Heifers over 2 years old	100	0.99	2.26	3.33
	150	1.49	3.39	5.0
	200	1.98	4.53	6.67
	250	2.48	5.66	8.33
	300	2.98	6.79	10.0
Gobies over 2 years old	100	0.01	0.02	0.03
	150	0.01	0.03	0.04
	200	0.02	0.04	0.06
	250	0.02	0.05	0.07
	300	0.03	0.06	0.09
Gobies up to 1 year	100	0.01	0.03	0.04
	150	0.02	0.04	0.06
	200	0.02	0.05	0.07
	250	0.03	0.06	0.09
	300	0.03	0.08	0.11
Boars producers	500	0.54	1.23	1.81
	1000	1.08	2.46	3.62
	1500	1.62	3.69	5.44
	2000	2.16	4.92	7.25
	2500	2.70	6.15	9.06
Sows	500	0.46	1.05	1.55
	1000	0.92	2.10	3.09
	1500	1.38	3.15	4.64
	2000	1.84	4.20	6.18
	2500	2.30	5.25	7.73
Suckling pigs	500	0.03	0.08	0.11
	1000	0.07	0.15	0.22
	1500	0.10	0.23	0.34
	2000	0.13	0.30	0.45
	2500	0.17	0.38	0.56
Weaning pigs	500	0.29	0.67	0.99
	1000	0.59	1.34	1.98
	1500	0.88	2.02	2.97
	2000	1.18	2.69	3.96
	2500	1.47	3.36	4.95
Fattening livestock of pigs	500	0.53	1.20	1.77
	1000	1.05	2.40	3.53
	1500	1.58	3.60	5.30
	2000	2.10	4.80	7.06
	2500	2.63	5.99	8.83
Replacement young growth	100	0.12	0.28	0.42
	150	0.19	0.42	0.62
	200	0.25	0.57	0.83
	250	0.31	0.71	1.04
	300	0.37	0.85	1.25
Ewes	25	0.01	0.01	0.02
	50	0.01	0.03	0.04
	100	0.02	0.05	0.08
	150	0.04	0.08	0.12
	200	0.05	0.11	0.16

Analyzing the data obtained (Table 3), it is clear that as the number of animals increases, the bioenergy efficiency coefficient will increase since E_{exit} is directly proportional to the number of livestock. And the E_{enter} value accordingly remains at the same level since it depends on the technical characteristics of the installations.

As can be seen from the data obtained (Table 3), all indicators of the bioenergy efficiency coefficient are of greater importance for the pilot plant. At the same time, the difference from the prototypes is, respectively, from the SV-10 by 3 times (70%), and from the P8-ORD-M by 1.5 times (32%). Thus, the developed installation will increase the economic effect compared to prototypes.

4 Conclusion

The developed experimental installation allows you to perform operations for the preparation of liquid feed mixtures for various types of animals. Taking into account the number of livestock for different groups of animals, the bioenergetic efficiency coefficient on average is: η_B=2.66 - heifers over 2 years old, η_B=0.05 - bulls over 2 years old, η_B=0.07 - bulls up to 1 year old , η_B=5.43 producer boars, η_B=4.63 – sows, η_B=0.33 – suckling piglets, η_B=2.97 – weaned piglets, η_B=5.30 – fattening piglets, η_B =0 .83 - replacement young stock and η_B=0.08 – ewes.

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