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INTRODUCTION OF ENERGY-SAVING TECHNOLOGIES FOR HARVESTING CEREAL CROPS TO PROVIDE LIVESTOCK WITH CHEAP FEED

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The technological operations of harvesting and transporting grain and the non-grain part of the harvest of cereal crops, which are among the most resource-intensive and energy-consuming operations, are studied. The minimum total energy consumption for harvesting and transportation of grain products per unit area was used as the main criterion for the formation and optimization of the structure and composition of harvesting technological complexes. The implementation of energy-saving technologies for growing and harvesting cereal grain crops solves the problems of technological re-equipment of agricultural enterprises to reduce the cost of work and obtain competitive livestock products, due to reducing cost of concentrated animal feed.

Key words: *fodder, livestock, grain crops, energy costs, energy saving, technological complex, technology.*

FORMULATION OF THE PROBLEM

The main factors of energy efficiency in providing livestock with fodder are the transition to advanced technologies and improvement of fodder production systems and animal feeding optimization. It has been scientifically established and confirmed in practice that only with full and balanced feeding, farm animals are able to fully realize their genetic potential. It has been proven that 55–60% of the productivity of animals is determined by the level and quality of feeding, while the influence of the breed is 25–30%, and the method of keeping and technology is 15–20% [1,2].

The continued use of traditional waste technologies for growing and harvesting agricultural crops does not contribute to obtaining the expected results: increasing productivity, gross production volumes, quality and reducing the cost of growing products. Therefore, in order to achieve the greatest efficiency in feed production, it is necessary to move towards the introduction of energy-saving and resource-saving technologies [3,4,5]. Only in this way will we be able to solve the problems of technical re-equipment of agricultural producers and obtain competitive crop and livestock products.

In order to reduce costs for producing plant products and livestock feed in conditions of constant growth in energy prices, it is necessary to implement energy-saving technologies for growing and harvesting agricultural crops. The largest costs of complex fuel energy and operational costs of funds fall on the final amount of mechanized work – harvesting. This is especially true for grain crops, which occupy one of the first places in terms of production in Ukraine.

Such production conditions indicate the need to find fundamentally new scientific solutions to its development. One of them is the reduction of technogenicity and the consumption of energy, fuel and operating costs during the cultivation and harvesting of agricultural crops. This substantiates the need for constant improvement of harvesting technologies and technical means for their implementation.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Combine harvesting of cereal grain crops is the main method in most countries of the world. At the same time, a separate (two-phase) method and direct harvesting (single-phase) are usually combined. Each of these methods has its advantages and disadvantages. Numerous data from scientific research institutions and production experiments show that in all natural and climatic zones and in years with different weather conditions a yield increase of 1.5 to 5 tons of grain from 1 ha or more is obtained

using a separate harvesting method in comparison with direct harvesting [6,7,8].
The separate harvesting method is widely used in the USA, Canada, England, and Sweden. In the USA, in recent years, 22.3% of ear crops and other crops have been collected separately, and in some parts, up to 70% have been collected separately. The separate method was used in Germany and other countries [9,10].
Today, in most countries of the world, the energy-saving technology is known as the zero tillage system. This technology is being introduced gradually, step by step. For minimal processing, special sets of machines are used, consisting of a powerful tractor, a wide-grip cultivator with a high-mounted frame for continuous soil treatment, and a stubble wide-grip planter. As the experience of the Ukrainian corporation "Agro-Soiuz" shows, switching to a minimal and then to a zero tillage system does not result in yield reduction. When growing corn for grain and silage, peas according to this technology, it even increases by 10...20 %.
With the zero system – the soil is not cultivated at all, but only sown with wide-grip stubble seed drills and harvested. "Agro-Soiuz" yields 60 centners/ha of winter wheat and 63.6 centners/ha of spring barley when using the zero system. Currently, about 100 million hectares, which is about 12% of all agricultural land, are cultivated using energy-saving technology in various countries of the world, and the volumes of its implementation are growing rapidly [9,11,12].

PRESENTING MAIN MATERIAL

To calculate the comparative assessment of energy costs – complex fuel and operating costs, four winter wheat harvesting technologies were considered [6]:
1. Traditional technology – direct harvesting without straw crushing
2. Traditional technology – separate combine harvesting of grain crops.
3. Zero technology – use of machinery and harvesters of domestic production.
4. Zero technology – use of imported harvesting equipment.

Technological maps for harvesting winter wheat have been developed [13,14] for these technologies, according to the methodology of the Ukrainian Scientific Research Institute of the Productivity of the Agro-Industrial Complex of the Ministry of Agrarian Policy of Ukraine "Standards of living and embodied labor costs for the production of grain crops" [6]. All technologies were developed for the following production conditions: cultivation area is 630 hectares; yield of the main products is 4.6 t/ha; yield of by-products is 4.6 t/ha. Normative yield losses are 3%; duration of harvesting when the grain is fully ripe is 7 days.
As a result of the statistical processing of data on the conditions of mechanized work according to the method presented above, distributions were built: the number of grain harvesters on farms, in the technological complex and the harvesting chain. The main parameters of the obtained experimental curves are shown in Table 1.

Table 1. Main distribution parameters characterizing the conditions of harvesting operations

Conditions grain harvesting	Statistical parameters of distributions					
	Average size, $\bar{X}$	Average quadratic deviation, σ	Dispersion, σ_2	Coefficient variations, V	Asymmetry, a_3	Kurtosis, a_4
Number of harvesters, units	9,84	2,82	7,94	0,29	0,03	2,49
The number of harvesters in technological complex, units.	9,31	2,59	6,68	0,28	1,14	4,15

The number of harvesters in the harvesting chain, units.	3,66	1,03	1,06	0,28	0,26	2,91

From the analysis of the data in Table 1, it can be seen that the average number of harvesters by farms and technological complex is approximately at the same level – 9.84 and 9.31 units with a root mean square deviation of 2.82 and 2.59, respectively, i.e., during harvesting operations in the farms of the region, one technological complex with the number of harvesters from 7 to 12 units is created. Based on the available data, histograms of these distributions were constructed – Figures 1, 2, 3.

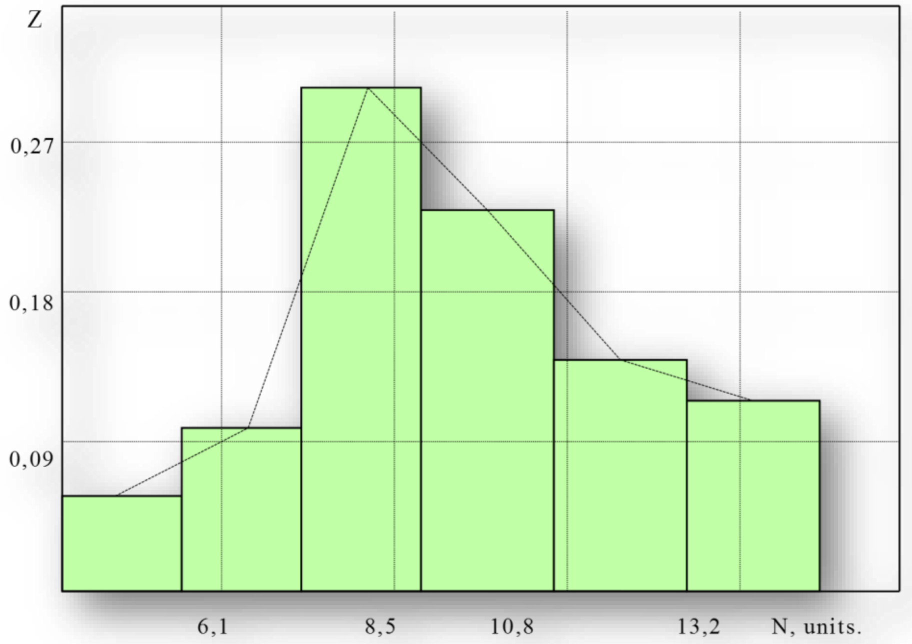

Fig. 1. Histogram of the number of harvesters (N, units) in farms

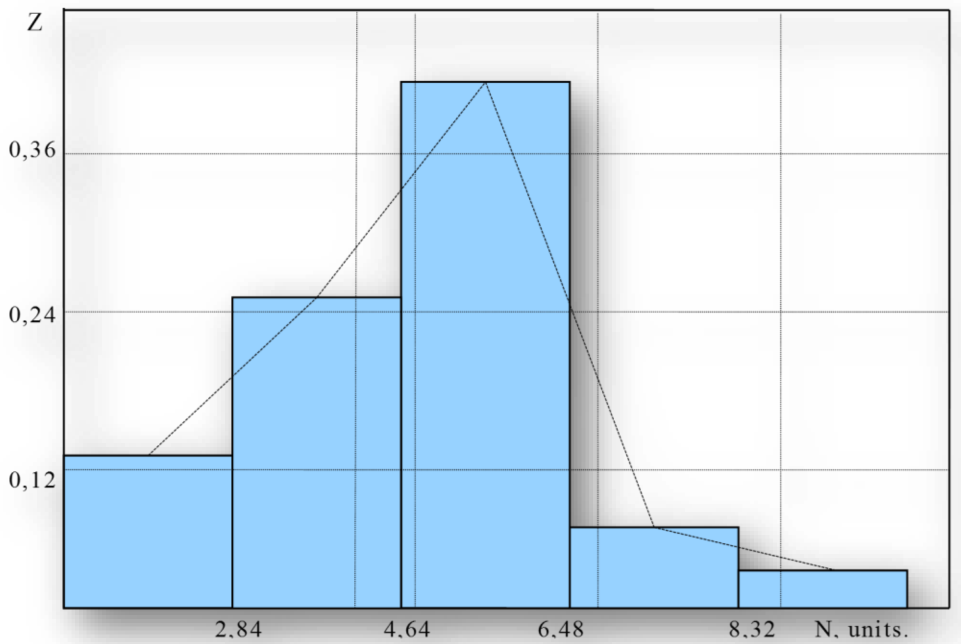

Fig. 2. Histogram of the number of harvesters (N, units) in the harvesting chain

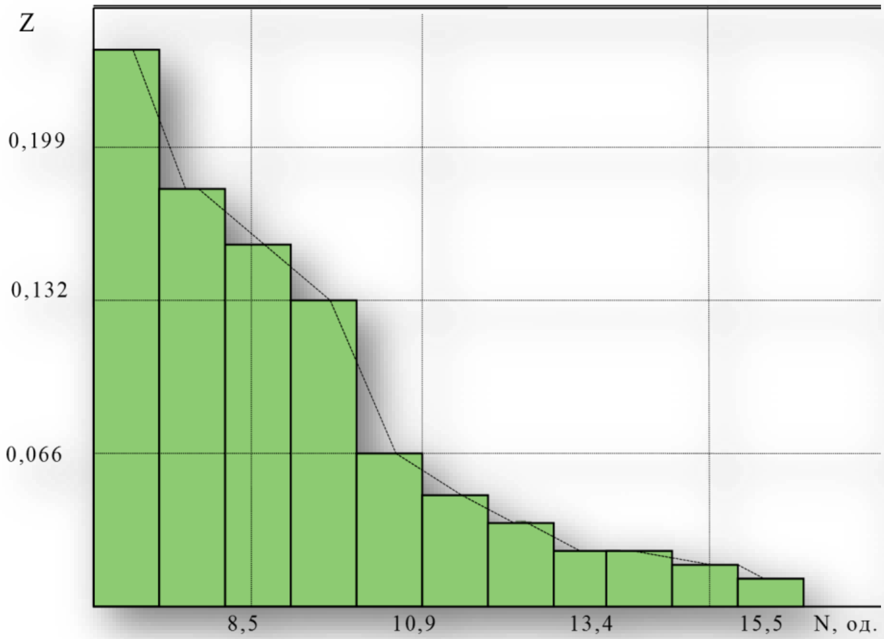

Fig. 3. Histogram of the number of harvesters (N, units) during harvesting

The formation of complex energy costs of harvesting grain crops based on direct fuel energy costs was determined according to the following method:

1. Formation of energy consumption of complex fuel for traditional technology – direct harvesting of grain

Calculation of fuel per 1 ha of harvesting area Q_{fha}, kg/ha was determined by the formula:

$$Q_{fra} = Q_f / F_{ha} \qquad (1)$$

where Q_f – the total fuel consumption for this technology, kg (Q_f=42787,7 kg);

F_{ha} – harvesting area, ha (F_{ha}=630 ha).

Energy costs E_f, MJ/ha of fuel energy were calculated according to the formula:

$$E_{f1} = \alpha_f \cdot Q_f, \qquad (2)$$

where α_f – the energy equivalent of fuel consumption, MJ/kg (α_f=52,8 MJ/kg [3]).

Energy consumption of fuel energy per unit of grown products E_{ft}, MJ/t – one ton of crop was determined by the formula:

$$E_{ft} = E_f / B_c \qquad (3)$$

where B_c – crop yield, t/ha (B_c=4,6 t/ha).

The results of calculations for all four technologies are presented in Table 2.

Table 2. Comparative assessment of complex energy costs for harvesting winter wheat

Harvesting technology	Energy costs, MJ			
	Complex fuel		Operating expenses (wages, fuel, depreciation, maintenance, repairs - current, capital)	
	Per unit of work, MJ/ha	Per unit of produced products, MJ/t	Per unit of work, MJ/ha	Per unit of produced products, MJ/t
1. Traditional - direct harvesting (with straw collection at	3586,0	779,6	2772,57	602,73

the complexes)				
2. Traditional - separate harvesting (with collecting straw at the edge of the field)	2821,9	613,4	2636,77	573,21
3. Zero technology - domestic production equipment (direct harvesting without straw collection)	2123,4	461,6	2106,1	457,85
4. Zero technology – imported harvesting equipment (direct harvesting without harvesting straw)	1893,8	411,7	2221,13	482,85

We perform a comparative assessment of energy consumption for different technologies of grain harvesting based on the calculation of operational costs (depreciation, maintenance and repair of equipment, wages, cost of fuel and lubricants) according to the following methodology [3].
Operating costs in units of measurement "USD /ha" are converted into units of measurement MJ/ha and MJ/t. At the same time, the energy equivalent of the fuel is used in translation into the monetary value of its complex cost.
The energy equivalent of fuel, $C_c^{\alpha f}$, MJ/ USD, was calculated according to the formula:

$$C_c^{\alpha f} = \alpha_f / C_c \qquad (4)$$

where C_c is the complex cost (price) of fuel and lubricants, hryvnias/kg
(C_c = 1,2 USD /kg).
$C_c^{\alpha f}$ =1,02 MJ/ USD.
The energy consumption of $E_{e\ ha}$, MJ/ha per 1 ha of the harvesting area was calculated according to the formula:

$$E_{e\ ha} = O_{e\ ha} \cdot C_c^{\alpha f} , \qquad (5)$$

where O_{ehai} – operating costs per 1 ha for the i-th technology, USD /ha, MJ/ha.
Energy consumption E_{cti}, MJ/t per 1 ton of winter wheat yield was calculated according to the formula:

$$E_{e\ ha} = E_{e\ ha} / Y_c , \qquad (6)$$

where Y_c is crop yield, t/ha.
All calculations of complex energy consumption of fuel and operating costs are presented in Table 2.

CONCLUSIONS

The results of the conducted research allow us to draw the following main conclusions:
1. The formation of the structure of technological complexes for harvesting grain crops determined the energy costs of complex fuel according to the developed technologies of winter wheat harvesting. They are: the lowest costs are with zero technologies, and the largest ones – with traditional harvesting technologies. Thus, energy consumption when using imported equipment – zero technology is the lowest: E_{f4}=1893,8 MJ/ha; E_{ft4}=411,7 MJ/t. The highest energy consumption is when using traditional – direct harvesting technology: E_{f1}= 3586 MJ/ha; E_{ft1}=779,6 MJ/t.
2. Energy costs, based on operating costs calculation, when justifying the composition of technological complexes for harvesting grain crops are as follows: the lowest energy costs in zero technology – domestic equipment, which amounted to: $E_{e\ 3\ ha}$ = 2106,1 MJ/ha; $E_{3\ t}$ = 457,85 MJ/t. The largest energy consumption is in traditional – direct harvesting technology, which amounted to: $E_{e\ 1\ ha}$ = 2772,57 MJ/ha; $E_{e\ 1\ t}$ = 602,73 MJ/t.

The implementation of energy-saving technologies for harvesting cereal crops will provide the livestock industry with cheap raw materials for producing affordable fodder.

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ВПРОВАДЖЕННЯ ЕНЕРГОЗБЕРІГАЮЧИХ ТЕХНОЛОГІЙ ЗБИРАННЯ ЗЕРНОВИХ КУЛЬТУР ДЛЯ ЗАБЕЗПЕЧЕННЯ ТВАРИННИЦТВА ДЕШЕВИМИ КОРМАМИ

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Досліджуються технологічні операції збирання й транспортування зерна і незернової частини урожаю зернових злакових культур , які відносять до найбільш ресурсномістких і енерговитратних операцій . В якості основного критерія формування і оптимізації структури та складу збиральних технологічних комплексів використовувалися мінімальні сумарні витрати енергії на збирання і транспортування продукції зернових з одиниці площі. Впровадженням енергозберігаючих технологій вирощування та збирання злакових зернових культур вирішуються проблеми технологічного переоснащення сільськогосподарських підприємств для зменшення собівартості робіт і отримання конкурентоздатної продукції тваринництва, за рахунок зменшення собівартості концентрованих кормів для худоби.

Ключові слова: *корм, тваринництво, зернові культури, енергетичні витрати, енергозбереження, технологічний комплекс, технологія.*