ENERGY EFFICIENCY OF PRODUCTION OF CATTLE BREEDING PRODUCTS OF MEDIUM-CAPACITY ENTERPRISES WITHIN THE SIMULATION MODEL PARAMETER SYSTEM

Valery MARCHENKO, PhD in Economic Sciences, Senior Researcher
https://orcid.org/0000-0002-9739-4987
Anatolii TKACHOV, PhD in Agricultural Sciences
https://orcid.org/0000-0002-6325-4724
Victoria PETRASH, PhD in Agricultural Sciences, Senior Researcher
https://orcid.org/0000-0001-9114-6117,
Olga PANCHENKO, PhD in Agricultural Sciences
https://orcid.org/0000-0003-2835-4938
Oleksandra LAMIEIKO, laboratory assistant
https://orcid.org/0009-0006-8810-3152
Livestock Farming Institute of the National Academy of Agrarian Sciences, Kharkiv, Ukraine

The results of monitoring the production and organizational indicators of more than 20 farms are presented with the definition of the main elements that characterize them. The relationship between the degree of technical support or technological equipment of the production process of milk production (quantitative composition of tractors, trucks, machinery, aggregates, milking equipment) and the annual productivity of cows is analyzed. Correlation coefficients indicate its moderate value (0.3<Rxy,<0.5). A simulation model of the production of cattle breeding products in the conditions of enterprises of medium production capacity has been created.

Technological elements that are characteristic of the rational process of production of products – milk, beef, live weight of animals in rearing and fattening-are substantiated. Within the technical parameters of enterprises with a number of cattle of 1000-1100 heads (350-450 cows with a capacity of 7000-9000 kg per cow), the annual total energy costs for the production of cattle products are determined.

The structure of the energy content of products by type is calculated, namely milk, live weight of culled animals, growth of reared animals, received offspring. The energy content of excrement and bedding is also taken into account. It is established that the largest share in the structure of the energy content of products suitable for nutrition belongs to the energy content of produced milk – 78.9–86.1 %, and since it is the most influential factor on the coefficients of energy efficiency of the main and general products, the functional dependences of the energy content of products on fat in milk and the relationship between the coefficients of energy content of products and milk fat are determined.

Keywords: energy consumption, energy efficiency, technology parameters, productivity, product quality.

ЕНЕРГОЕФЕКТИВНІСТЬ ВИРОБНИЦТВА ПРОДУКЦІЇ СКОТАРСТВА ПІДПРИЄМСТВ СЕРЕДНЬОЇ ПОТУЖНОСТІ В МЕЖАХ СИСТЕМИ ПАРАМЕТРІВ ІМІТАЦІЙНОЇ МОДЕЛІ

Валерій МАРЧЕНКО, к. екон. н., с. н. с., https://orcid.org/0000-0002-9739-4987
Анатолій ТКАЧОВ, д. філос. з аграр. н. та прод.
https://orcid.org/0000-0002-6325-4724
Вікторія ПЕТРАШ, к. с.-г. н., с. д., https://orcid.org/0000-0001-9114-6117
Ольга ПАНЧЕНКО, к. с.-г. н., https://orcid.org/0000-0001-9580-2839
Олександра ЛАМЕЙКО, лаборант, https://orcid.org/0009-0006-8810-3152
Інститут тваринництва НААН, Харків, Україна

Наведено результати моніторингу виробничо-організаційних показників понад 20 господарств з визначенням головних елементів, якими вони характеризуються. Проаналізовано зв'язок ступеня технічного забезпечення або технологічного оснащення виробничого процесу одержання молока (кількісний склад тракторів, вантажівок, техніки, агрегатів, доїльного обладнання) і річної продуктивності корів. Коефіцієнти кореляції свідчать про його помірну величину (0,3<Rxy,<0,5). Створено імітаційну модель виробництва продукції скотарства в умовах підприємств середньої виробничої потужності.

Обґрунтовані технологічні елементи, що характерні раціональному процесу виробництва продукції – молока, яловичини, живої маси тварин на вирощуванні та відгодівлі. У межах технічних параметрів підприємств з чисельністю поголів'я великої рогатої худоби 1000-1100 голів, (350-450 корів із продуктивністю 7000-9000 кг на корову) визначені річні загальні затрати сукупної енергії на виробництво продукції скотарства.

Обчислена структура енерговмісту продукції за видами – молоко, жива маса вибракуваних тварин, приріст тварин, що вирощуються, отриманий приплод. Ураховані також енерговміст екскрементів і підстилки. Встановлено, що найбільша частка в структурі енерговмісту продукції, придатної для харчування належить енерговмісту виробленого молока – 78,9–86,1 %, і оскільки воно є найбільш впливовим чинником на коефіцієнти енергетичної ефективності основної і загальної продукції визначені функціональні залежності енерговмісту продукції від жиру в молоці та взаємозв'язок коефіцієнтів енерговмісту продукції і жиру молока.

Ключові слова: енерговитрати, енергетична ефективність, параметри технології, продуктивність, якість продукції.

Management in the conditions of rational use of resource potential is the key to the success of production and directly contributes to the development of the livestock industry. In today's conditions, the creation and maintenance of such a production structure is a complex, but relevant at any time task, since existing farms mostly do not sufficiently meet the requirements of the market environment – they are moderately competitive in terms of technical equipment, technological processes in production, and not always high-quality products (Gadzalo et al., 2016; Baschenko et al., 2017; Vedmedenko & Kovalenko, 2020). An increase in the load of production processes on the environment increasingly causes its reverse reaction in the form of deterioration of soil fertility, changes in climatic conditions, which in turn affects the energy efficiency of cattle production (Rudenko et al., 2008; Rudenko et al., 2017; Marchenko et al., 2020; Marchenko et al., 2023; Busenko, 2005 ; Kostenko & Kravchenko, 2019).

At the present stage of development of the cattle breeding industry, an essential point is to ensure optimal production indicators (live weight of young animals, average daily increments, gross production, etc.), in the conditions of break – even production-that is, its corresponding cost and sales price (Rudenko et al., 2008; Pankeev, 2022; Pidpala, 2008; Ruban Y. & Ruban S., 2011).

Previous studies of milk production technologies for medium-sized enterprises (with a population of 400 cows) allowed to develop their organizational, production and economic parameters in conditions of fixed high productivity (8000 kg of milk per cow per year) (Marchenko et al., 2020; Getmanets, 2012). Prior to this, consumption standards were defined separately and patterns of their changes were established under conditions of different cow productivity (from 4,000 to 9,000 kg of milk per year) (Getmanets, 2012; Baranovsky et al., 2017). At the same time, changes in climate and other global conditions indicate that the efficiency of existing technological solutions is suboptimal in terms of energy efficiency of production, including taking into account the quality of raw materials or finished products (Rudenko et al., 2008; Marchenko et al., 2019; Marchenko et al., 2023; Ibatullin et al., 2016 ; Kostenko & Kravchenko, 2019).

It should be noted that among 1,533 enterprises, 129 (8.4% of the total number) are those that keep from 1,000 to 1,499 heads of cattle and whose share in the total structure of the cattle population is 16.6 %. Currently, among the total number of 1,400 enterprises, 614 (42.7% are enterprises with 100-499 cows), the same share is 40.0%, that is, they are a significant sector both in terms of livestock and milk production (Tvarinnitstvo, 2023). At the same time, the technologies used by such enterprises for the most part do not always meet the requirements of modernity, and the quality of milk or raw materials needs to be improved to a level that ensures high competitiveness (Kostenko et al., 2010; Kostenko, 2018).

Within the specified parameters of pilot projects or their feasibility studies, it is impossible without establishing and taking into account the Basic Laws of energy efficiency formation of technological processes of production to create in practice in each specific case an energy-efficient, scientifically justified, innovatively attractive technology for the production of products of the required quality (Rudenko et al., 2008; Getmanets, 2012; DBN00037, 1995; Ibatullin et al., 2016; Bogdanov et al., 2012). The conducted research is aimed at establishing exactly such regularities in the formation of energy efficiency of technological processes for the production of high-quality livestock products in the context of climate change. They take into account the directions of savings by types of resources (including labor and material) and, as a result, have an overall positive result.

Directions for further improvement or principles of building basic technological processes in the production of cattle breeding products for medium-sized enterprises are determined using modeling and margin analysis methods. The regularities of the use of energy resources are aimed at improving or more rational their use by Type (human, material, land), respectively, taking into account the dependence of changes in product quality (Merkurieva, 1980 ; Petrenko & Syrotyuk, 2021).

The object of the study was selected agricultural enterprises for the production of milk of medium capacity with a number of cows up to 500 heads.

The purpose of the research is to find out the regularities of the formation of an energy – efficient system of parameters and standards of technological and technical solutions for the production of cattle products when creating enterprises of medium production capacity.

Materials and methods of research. According to various methods (economic-statistical, economic-mathematical, expedition surveys, modeling, etc.) using the

methodology of bioenergy assessment of production technologies (Kulik et al., 1997), as well as official reports, monitoring, analysis and generalization of the components of the production process in the conditions of tethered and loose methods of keeping cattle were carried out.

Research results. Monitoring and generalization of technological and technical solutions of enterprises of medium production capacity allowed to use technological passports of production of dairy cattle products of a number of farms-SE " DG "Agronomy" is Naas of Ukraine", SE "DG" Artemida" IC Naas of Ukraine", SE "DG Institute of Agriculture of the north-east of the NA-an", SE" DG" Gontareva "it Naas of Ukraine", SE" DG "elite" of the Mironovsky wheat institute named after V. M. Crafts of Naas", Dpdg "elite" of Kirovohrad DSGDS of Naas, Dpdg "Alexandrovskoe" SPC "soy of Naas, Dpdg "Pasechnaya", SE DG "Hristinovskoe" Irgt named after M. V. Zubets, Dpdg Shevchenko" Ibkitsb of Naas, Dpdg "Ivanovka" ISGPS of Naas, SE "DG named after January 9" of the Institute of pig breeding and APV of the Naas of Ukraine", SE "DG im. Decembrists", state enterprise "experimental base "Dachnaya". The distribution of cows according to the systems of keeping is established – free (boxed, deep bedding) – 22 %, on a leash – 78 %. Productivity - at the level of 6470 kg and 4480 kg, respectively (the advantage of the loose maintenance system is 1.4 times). Various milking technologies were analyzed – in stalls (milking buckets) – 27 %, in stalls (milk pipeline) – 51 %, in the milking parlor-22% with milk productivity of cows up to 4000 kg, up to 6000 kg and up to 7000 kg of milk per cow, respectively. The use of additional technical means for the preparation and distribution of feed makes it possible to use the feed mixture feeding system. The distribution of cows by feeding Technologies was 70 % (separate ration by Feed type), and 30 % (for the use of feed mixtures). It is established that under such conditions there is an increase in the milk productivity of cows by more than 2100 kg per head. A limiting factor in the growth of cow productivity is also the problem with reproduction with any technology, as indicated by the significant variability in the yield of calves per 100 cows-from 51% to 97 %.

The influence of the intensity of animal rearing with the achievement of a certain fatness on the energy consumption of production is studied. Data on the average daily growth of calves under various technologies of their maintenance were obtained and analyzed. So, from birth to 2 months of age, subject to the following distribution of animal maintenance technology: 29%-on a leash, 25% – in Group machines and 46% – in individual machines, respectively, productivity levels – 476 g, 409 g and 542 g of average daily growth. Fatness is average for all cases. At an older age, the productivity of young animals was 452 G on a leash, with loose content – an increase of 12.6 % (509 g). Therefore, for a pilot project, it is more appropriate to choose the technology of loose content. On the basis of statistical data for Ukraine of the last two years, the relationship between the degree of technical support or technological equipment of the production process of milk production (quantitative composition of tractors, trucks, machinery, aggregates, milking equipment) and the annual productivity of cows is analyzed. Correlation coefficients indicate its moderate value (0.3<Rxy,<0.5).

Thus, the generalization of data of agricultural milk producers, including information on the state enterprise DG network of the National Academy of Sciences of Kharkiv and other regions of Ukraine, allowed to substantiate the system of parameters and standards of technological and technical solutions in the creation of enterprises of medium production capacity, which showed the best results in terms of milk productivity in conditions of different technologies of maintenance, milking systems, cow feeding, intensity of young growth (Marchenko, 2020; Tvarinnitstvo, 2023).

It should be noted that since the strength of the influence of the studied

technological factors (conditions) on the overall productivity of cows and young animals is complex and complex, therefore, in the first approximation to the system of parameters and standards of technological and technical solutions for the simulation model, such, from our point of view, the most acceptable option is chosen, namely, the technology of uniform production of marketable products (milk, beef, breeding cattle). For modeling, the average annual number of cows in the range of 350-450 heads with an annual productivity of 7000-9000 kg of milk per head was taken.

The calculated volumes of feed supply, livestock and their productivity make it possible to obtain an annual shaft of milk of 2300-3800 tons. Taking into account its drinking to calves, the size of milk sales will be 2160-3570 tons (marketability of 94 %). Meat from culled and fattened cattle – 190-198 tons, in live weight, including 70-90 heifers.

Herd structure – cows-30.4 – 33.8 %; heifers-5.8 – 6.0 %; heifers older than one year-13.8 – 14.8 %; heifers up to one year-18.4 – 20.6%; bitches older than one year – 9.8%, bitches up to one year-18.4%. Rejection and replacement of the main herd – 20-22 % (actual cultivation of repair heifers), full turnover of the herd. The method of keeping livestock is loose, using straw bedding. It provides for the cultivation and fattening of bitches on the farm to a live weight of 430-450 kg (900 g of average daily growth). The age of the first insemination of heifers with a live weight of 1 head is 380-400 kg at 15-16 months. The average daily growth of heifers up to a year is at the level of 760 g, older than a year – 800 g. the care of young animals is 4-6 %.

Feed supply of cattle herds is based on a system of the same type of feeding with feed mixtures. The yield of grain and fodder crops per 1 ha of sowing: cereals on average – 35-72 C, winter wheat – 38-60 C, barley – 32-46 C, corn for grain – 56-90 C, peas – 19-26 C, corn for silage – 270-290 C, perennial grasses for hay – 45-55 C and for haylage and green fodder – 270-290 C. Initial data for determining energy costs for the production of dairy cattle products - costs for a cow with a plume: labor – 60-65 people.- H;, the average annual Head of young animals – 18.0 people.- H., electricity-680-720 kWh. Energy equivalents of other resources-according to certain or known reference values (Rudenko et al., 2008; Kulik, 1997).

To ensure the required levels of productivity, annual feed harvesting and consumption rates and their structure for cows and repair heifers have been developed, depending on their productivity (Rudenko et al., 2008). These standards are based on the norms of the need for nutrients and feeding of animals, taking into account their sex and age composition and physiological state, live weight and productivity, seasons of the year (winter and summer), requirements for the quality of milk, the need for feed to maintain life and products, biological and technological losses of feed during harvesting, storage, delivery and feeding, energy consumption for growing grain and feed crops and Feed Production, their prime cost, etc. According to the standard, to obtain milk yields of 7000-9000 kg of milk, it is necessary to prepare 78-95 centners of feed units (89-110 GJ of exchange energy) per cow per year. At the same time, the type of feeding of cows and young cattle is formed in the direction of increasing the consumption of Grain Group feed in animal diets (50-54%), and their use is only as compound feeds, which are full – fledged in composition, provide a given productivity and meet the needs of the physiological state of cows and other sex and age groups of young animals. In the composition of mixed feeds by weight, grain accounts for no more than 80% and 20% are additives. Of the total amount of grain for the production of mixed feeds, 30% of the nutritional value is occupied by corn, barley and wheat and 10% by peas, and in additives at least 50% is occupied by high - protein components (meal, cake, etc.). Feeding of all types of feed, including mixed feed as part of complete feed mixtures. The size of the

feed fund is determined in accordance with the standard of accounting for the insurance reserve – for concentrates – 8-10%, juicy and coarse feed – up to 15 %.

The total nutritional requirement for a dairy farm of 350 cows, depending on their productivity (7000-9000 kg), is respectively 4910-5870 tons of feed units, of which it is necessary to prepare in kind: mixed feed – 1608-2082 tons, silage – 4407-4919 tons, hay of perennial grasses – 949-1138 tons, hay of annual grasses – 433-569 tons, haylage of perennial grasses – 1924-1700 tons and green fodder – 2384-2539 tons.

For a dairy farm for 450 cows (depending on their productivity of 7000-9000 kg), the total nutritional requirement is 6309-7550 tons of feed units, of which it is necessary to prepare in kind: mixed feed – 2067-2677 tons, silage – 5666-6324 tons, hay of perennial grasses – 1216-1463 tons, hay of annual grasses – 557-732 tons, haylage of perennial grasses – 1527-2186 tons and green fodder – 3065-3264 tons.

Variants of calculations within the parameters of productivity (7000-9000 kg per cow) with the total number of cattle herds of 1000-1100 heads (350-450 cows) showed that the density of the average annual livestock on its own feed base per 100 hectares of farmland is respectively – cattle – 92-82 heads, including cows – 29-26 heads.

The annual total cost of total energy for production (milk, growth, Live weight) is determined.

According to the structure within the standard size of 350 cows, the total total energy costs are as follows: 9.3–7.6 % – for herd reproduction, 1.8–1.5 % – from fixed assets of production, 3.5–3.0 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 2.0 – 1.7 %, the total energy converted in feed and litter is 83.4–86.1 %. It was found that for 350 cows with a plume with an increase in productivity from 7000 kg/head to 9000 kg/head. (by 28.6 %) total total energy costs for production increase by only 16.3 % – from 155,152 GJ to 180,346 GJ (or from 443 GJ to 515 GJ per cow).

According to the structure within the standard size of 400 cows, the total total energy costs are as follows: 9.3–7.6 % – for herd reproduction, 1.6–1.4 % – from fixed assets of production, 3.5–3.0 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 1.8 – 1.5 %, the total energy converted in feed and litter is 83.8–86.5 %. For 400 cows with a plume with an increase in productivity in the same range (28.6%), total and specific energy costs for production increase by 16.3% from 176568 GJ to 205350 GJ (or from 441 GJ to 513 GJ per cow).

According to the structure within the standard size of 450 cows, the total total energy costs are as follows: 9.4–7.6 % – for herd reproduction, 1.6–1.4 % – from fixed assets of production, 3.5–3.0 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 1.8 – 1.5 %, the total energy converted in feed and litter is 83.7–86.5 %. For 450 cows with a plume with an increase in productivity by the same 28.6%, the total total energy expenditure for production increases by 16.4% from 197986 GJ to 230373 GJ (or from 440 GJ to 512 GJ per cow).

Thus, if we compare the total energy costs in absolute values and within any one level of productivity of either 7000 kg, 8000 kg or 9000 kg, then they increase linearly by 42834 GJ; 46282 GJ and 50027 GJ per 100 additional cows within the limits of productivity increase-from 7000 kg to 9000 kg of milk, respectively. At the same time, per 1 cow, the cost of total energy practically does not depend on their productivity. Thus, they decrease by 0.7 % for 7000 kg and 8000 kg of milk yield and amount to 443 and 478 GJ (350 cows), respectively; 441 and 476 GJ (400 cows) and 440 and 474 GJ (450 cows). At 9,000 kg, a 0.6% reduction is 515 GJ (350 cows) versus 512 GJ (450 cows). Consequently, increasing the capacity of the enterprise by increasing the number of cows requires additional costs of total energy, depending on their productivity level of 7000

kg; 8000 kg; 9000 kg at the level of 428.3 GJ/head; 462.8 GJ/head and 500.3 GJ/head, respectively. There is no significant difference in the structure of energy costs.

So, the use of the energy efficiency assessment of production (milk, growth, Live weight) according to the indicator of annual total energy costs allowed us to determine that increasing the productivity of cows requires additional energy costs in the amount of 16.3–16.4% to the "conditionally initial base level", regardless of the standard size and per 1 kg of added milk corresponds to 0.036 GJ of total energy.

Using the developed algorithm of the MS Excel Office program within the system of parameters of the simulation model, a margin analysis by types of energy consumption was carried out and the dependences of changes in energy efficiency of production were modeled, taking into account the energy content of milk and its primary qualitative characteristic – fat (Merkurieva, 1980).

It is established that the energy content of products produced within reasonable technological parameters and directly suitable for consumption with an increase in productivity from 7000 kg to 9000 kg (28.6 %) increases from 8929 GJ to 11088 GJ. (24.2 %) for 350 cows and from 11,480 GJ to 14,256 GJ (24.2%) for 450 cows. The largest share in the structure of energy content of products suitable for food, namely, the energy content of produced milk occupies – 84.2 % (350 cows) and 87.2 % (450 cows), respectively, which is the determining factor of both the coefficient of energy efficiency of products suitable for food and the total product.

The structure of the energy content of products by type for the capacity variant of 7000 kg; 8000 kg and 9000 kg of milk per cow per year is shown in Table 1.

Table 1.

Structure of energy content of products by type, %

Energy content, GJ:	cow productivity, kg / year		
	7000	**8000**	**9000**
obtained milk (with a fat content of 3.8 %)	84.2	85.9	87.2
live weight of culled animals	10.0	9.0	8.2
offspring received for the year	0.9	0.8	0.7
weight gain of reared animals	4.9	4.3	3.9
products suitable for food	100	100	100

For productivity from 7000 kg to 9000 kg per cow per year with an interval of growth of fat content in milk by 0.1% from 3.8% to 4.2%, it was determined that the coefficient of energy efficiency of products suitable for nutrition slightly improves from 5.45-6.42 % (350 cows) with an increase in the number of cows to 5.49–6.46 % (450 cows). The energy efficiency coefficient of total products increases from 25.6% -26.8% to 25.8–27.0% in accordance with the standard size and productivity level of cows. Patterns of changes reflect graphical dependencies in figures 1-6.
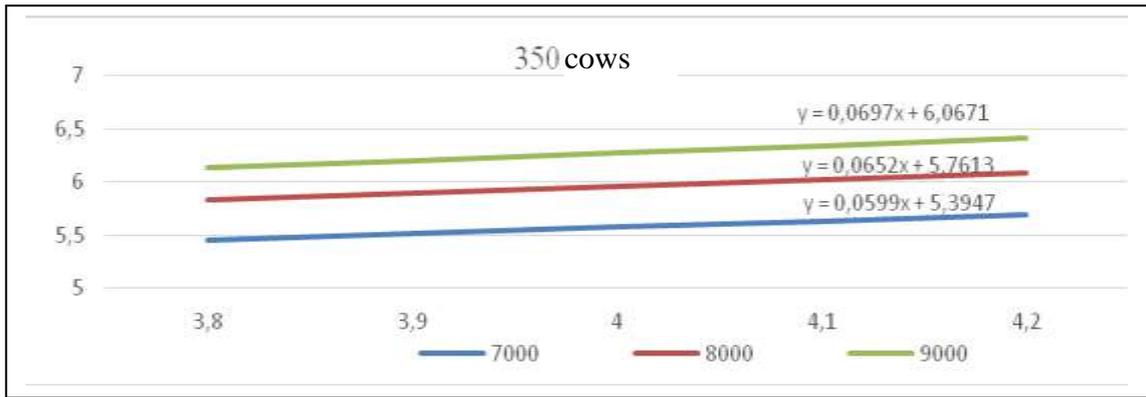
Fig. 1. **Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.**
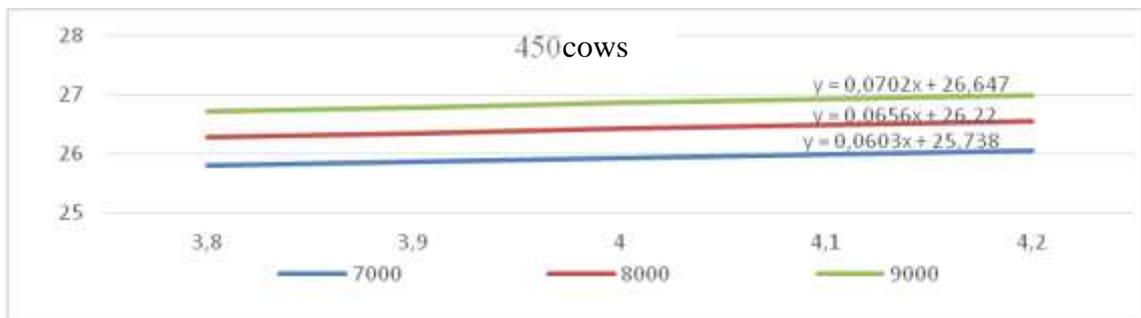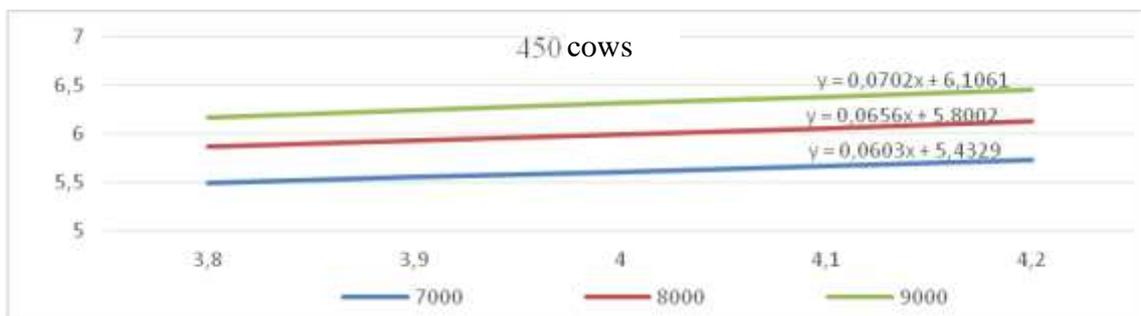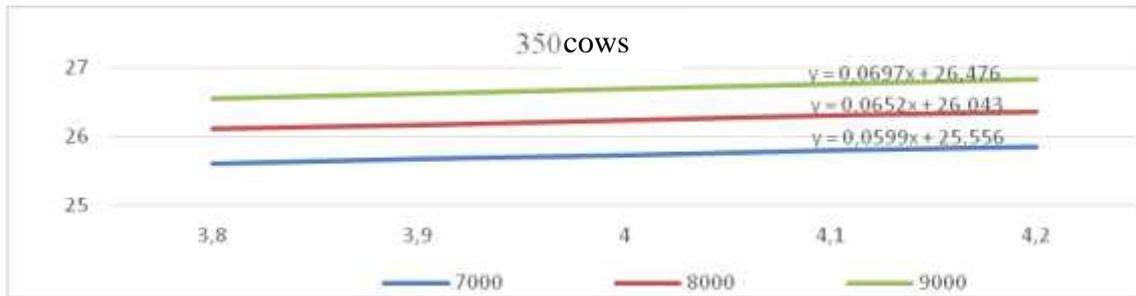

Fig. 2. **Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.**

Fig. 3. **dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.**

350 cows

$$y = 0{,}0697x + 26{,}476$$
$$y = 0{,}0652x + 26{,}043$$
$$y = 0{,}0599x + 25{,}556$$

Fig. 4. **Dependence of the energy efficiency coefficient of total production on the fat content in milk and cow productivity.**
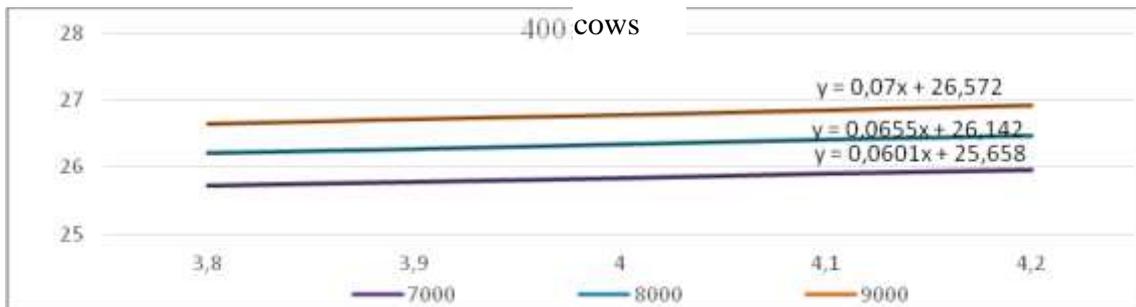

400 cows

$$y = 0{,}07x + 26{,}572$$
$$y = 0{,}0655x + 26{,}142$$
$$y = 0{,}0601x + 25{,}658$$

Fig. 5. **Dependence of the energy efficiency coefficient of total production on the fat content in milk and cow productivity.**

450 cows

$$y = 0{,}0702x + 26{,}647$$
$$y = 0{,}0656x + 26{,}22$$
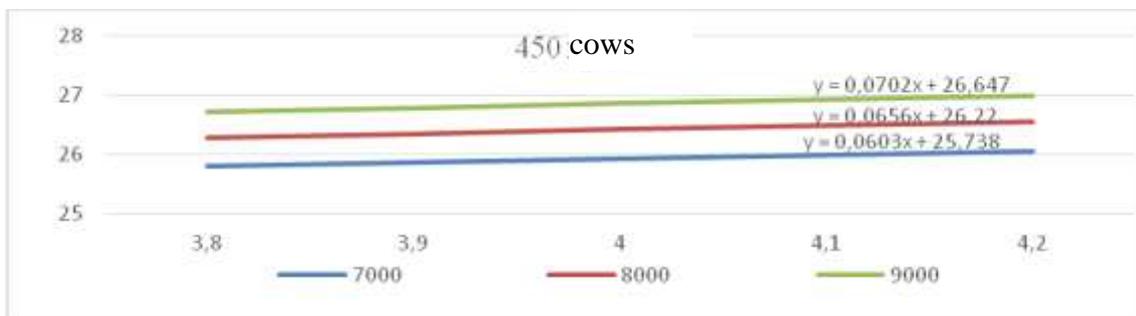$$y = 0{,}0603x + 25{,}738$$

Fig. 6. **Dependence of the energy efficiency coefficient of total production on the fat content in milk and cow productivity.**

Under the same conditions, namely, for productivity from 7000 kg to 9000 kg per cow per year with an interval of growth of fat content in milk by 0.1% from 3.8% to 4.2%, regularities of changes in the energy content of products suitable for nutrition and the energy content of all products, taking into account the combined one, are established. The patterns of changes reflect the graphical dependencies in figures 7-12.
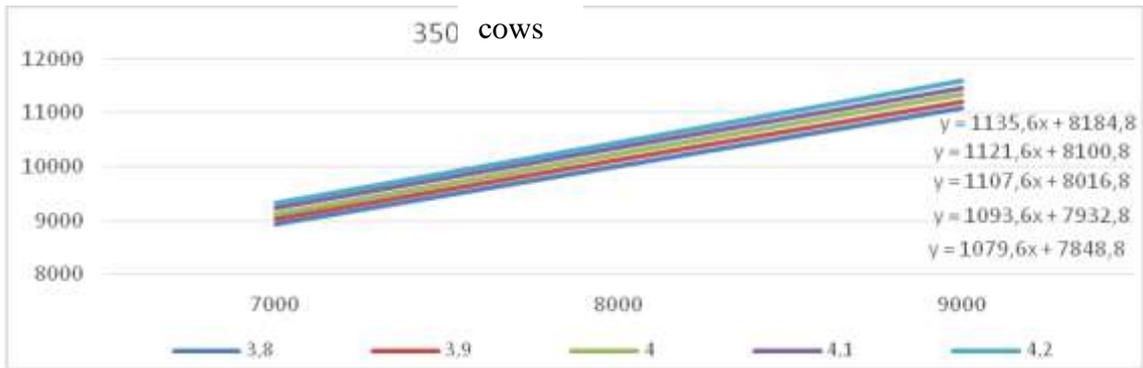
Fig. 7. **Dependence of the energy content of products suitable for nutrition on the fat content in milk and productivity of cows.**
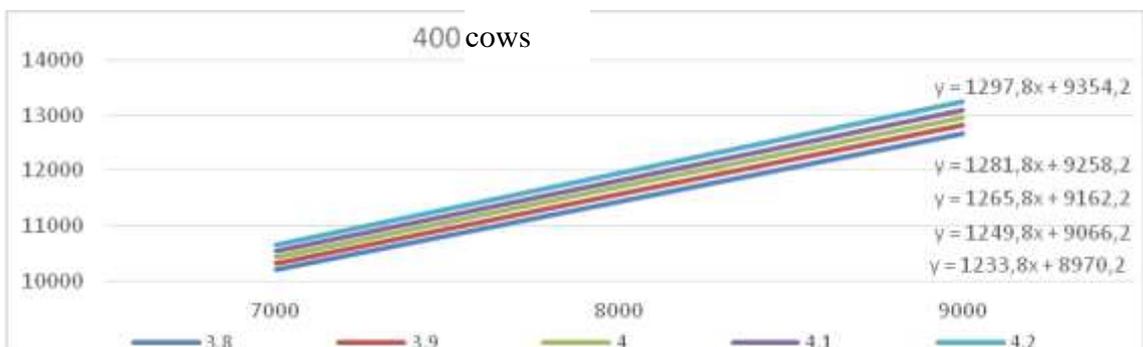

Fig. 8. **Dependence of the energy content of products suitable for nutrition on the fat content in milk and productivity of cows.**
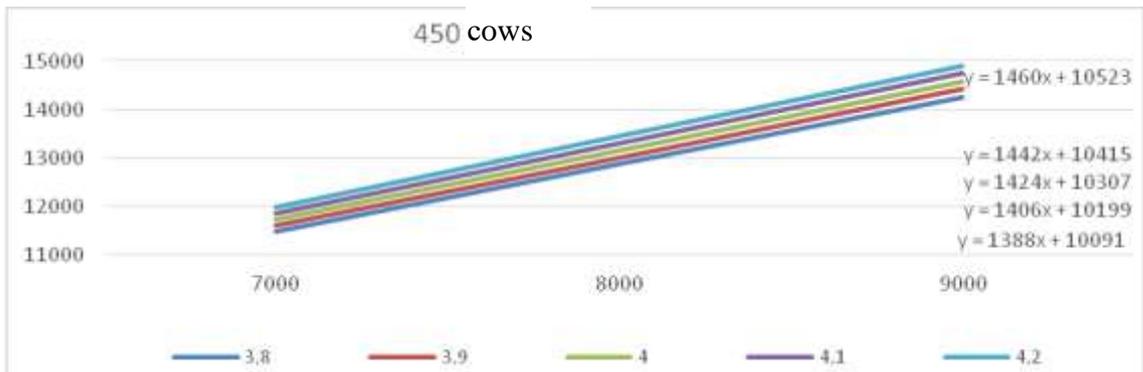

Fig. 9. **dependence of the energy content of products suitable for nutrition on the fat content in milk and productivity of cows.**

Fig. 10. **dependence of the energy content of all products, taking into account conjugated products, on the fat content in milk and cow productivity.**

Fig. 11. **Dependence of the energy content of all products, taking into account conjugated products, on the fat content in milk and cow productivity.**
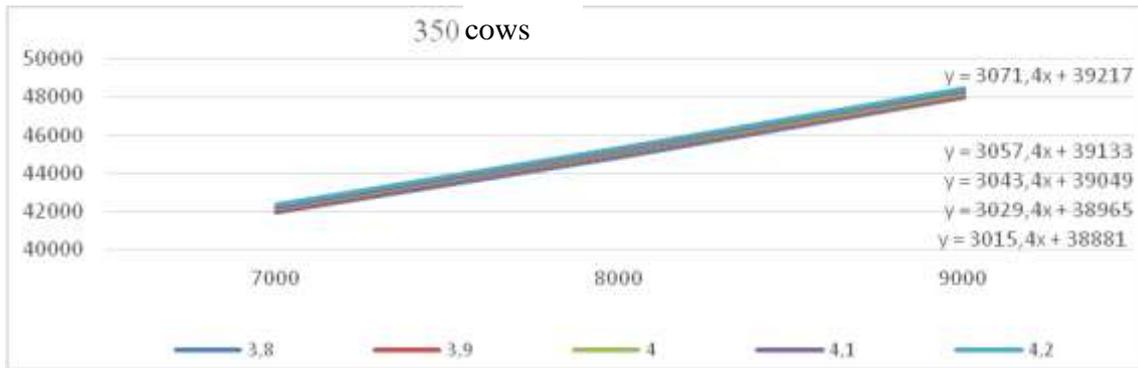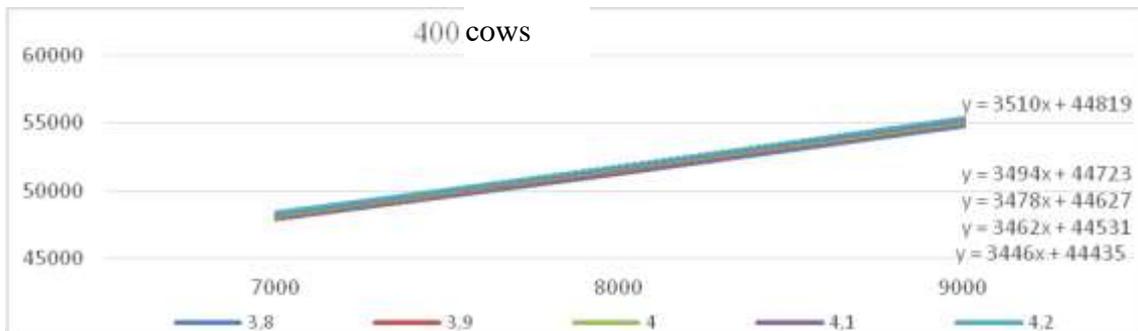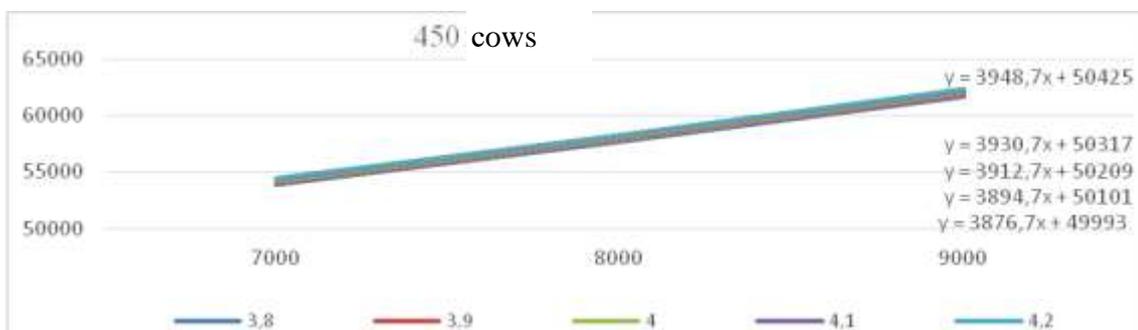

Fig. 12. **Dependence of the energy content of all products, taking into account conjugated products, on the fat content in milk and cow productivity.**

The established linear dependencies prove the general axiom that regardless of the fat content in milk, with an increase in productivity, there is an increase in both the energy content of products suitable for nutrition and the energy content of all products. At the same time, both an increase in the number of cows and their productivity affects the growth of absolute indicators. The result of productivity growth for every 1000 kg is an increase in this energy content by 1079-1135 GJ (350 cows with a plume), 1234-1298 GJ (400 cows), 1388-1460 GJ (450 cows) or by 5.2% in accordance with the quality of milk in terms of fat content. For the energy content indicator of all products, the corresponding increase is by 2914-2970 GJ; 3331-3395 GJ; 3747-3819 GJ or by 1.9 %. Based on 1 cow with a plume, the dependencies are shown in Table 2.

Table 2.

Energy content of products suitable for nutrition, and energy content of all products in accordance with the fat content in milk.

Fat content of milk (X), %	Energy content of products suitable for nutrition (Y), GJ per 1 cow with a plume	Energy content of all products including conjugated (Y), GJ per 1 cow with a plume
3,8	y = 3,0846x + 22,425	y = 8,6153x + 111,09
3,9	y = 3,1246x + 22,665	y = 8,6553x + 111,33
4,0	y = 3,1646x + 22,905	y = 8,6953x + 111,57
4,1	y = 3,2046x + 23,145	y = 8,7353x + 111,81
4,2	y = 3,2446x + 23,385	y = 8,7753x + 112,05

In the conditions of increasing the productivity of cows from 7000 kg of milk to 9000 kg of milk, the coefficients of energy efficiency of products suitable for nutrition and total products, respectively, the quality characteristics of milk change in the direction of improvement in the following dependence (Table. 3 and Table. 4).

Table 3.

Relationship between the energy efficiency ratio of food-friendly products (Y),%, and milk fat (X), %

Milk fat content (X), %	number of cows, heads		
	350	400	450
3,8	y = 0,3412x + 5,1236	y = 0,3414x + 5,1454	y = 0,3415x + 5,1620
3,9	y = 0,3461x + 5,1787	y = 0,3463x + 5,2007	y = 0,3465x + 5,2175
4,0	y = 0,3511x + 5,2337	y = 0,3513x + 5,2560	y = 0,3514x + 5,2730
4,1	y = 0,3560x + 5,2888	y = 0,3562x + 5,3113	y = 0,3564x + 5,3284
4,2	y = 0,3609x + 5,3439	y = 0,3612x + 5,3666	y = 0,3613x + 5,3839

Table 4.

Relationship between the energy efficiency ratio of total production (Y),%, and milk fat (X), %

Milk fat content (X), %	number of cows, heads		
	350	400	450
3,8	y = 0,4650x + 25,160	y = 0,4619x + 25,265	y = 0,4593x + 25,348
3,9	y = 0,4699x + 25,215	y = 0,4669x + 25,321	y = 0,4643x + 25,404
4,0	y = 0,4749x + 25,270	y = 0,4718x + 25,376	y = 0,4692x + 25,459
4,1	y = 0,4798x + 25,325	y = 0,4767x + 25,431	y = 0,4742x + 25,515
4,2	y = 0,4847x + 25,380	y = 0,4817x + 25,487	y = 0,4791x + 25,570

Thus, it is proved that both increasing productivity and improving the quality of milk has a positive effect on the energy efficiency of production.

Discussion. According to many scientists, the effective use of the resource potential of cattle breeding enterprises is an urgent problem today, and therefore the materials of our research are aimed at deepening solutions to this complex problem

because they coincide with common challenges. In this context, it should be taken into account that ensuring the necessary production indicators in the conditions of break-even production from an economic point of view is aimed at achieving the corresponding cost of production in the conditions of actual sales prices. Since the price does not fully (indirectly) describe the characteristics of energy costs of resources, more adequate, in our opinion, is the application of energy assessment and calculation of resource requirements through natural indicators of parameters and standards of production technology.

Our analysis and numerous studies have confirmed the facts that existing technologies do not always meet the requirements of our time, and the quality of milk or raw materials needs to be improved to a level that ensures high competitiveness.

Monitoring and generalization of technological and technical solutions of enterprises of medium production capacity allowed us to analyze the systems of keeping animals, the relationship between the degree of technical support for the production process of milk production, establish inhibitory or contributing factors of influence and determine the initial parameters when creating a simulation model.

Within the specified parameters of the multi-factor simulation model of medium-capacity enterprises, calculations are made and regularities of energy efficiency formation are established, which are disclosed in the presented materials.

The substantiated dependencies and established regularities make it possible, taking into account the qualitative characteristics of products (milk fat), to form the main technological elements of the cattle production system within the parameters of medium-sized enterprises (350-450 cows with a plume). Modeling of production using equations of dependence of its energy content on qualitative characteristics makes it possible to objectively assess the energy components of individual technological processes in the production of products by types of resources. This is of wide practical importance, since the energy efficiency of technological solutions directly correlates with the efficiency of the livestock production process.

Conclusions:

1. Monitoring and analysis of technological and technical solutions of enterprises of medium production capacity, which showed the best results in milk productivity in the conditions of various technologies of maintenance, milking systems, feeding cows, the intensity of young growth allowed to justify the initial parameters and standards of technological and technical solutions. This, in the conditions of regulated product quality and the use of the developed algorithm for modeling the energy efficiency levels of its production, makes it possible to create feasibility studies for pilot projects of enterprises of this type.

2. A correlation analysis of statistical data for Ukraine over the past two years is carried out. The strength of the impact on the annual productivity of cows of the degree of technical support or technological equipment of the production process of milk production (quantitative composition of tractors, trucks, machinery, aggregates, milking equipment) is estimated. Correlation coefficients indicate a moderate association between traits $(0.3 < R_{xy}, < 0.5)$.

3. It was found that the energy content of products directly suitable for consumption with an increase in productivity from 7000 kg to 9000 kg increases from 9532 GJ to 11683 GJ (by 22.6 %) for 350 cows and from 11670 GJ to 14436 GJ (by 23.7 %) for 450 cows. The largest share in the structure of energy content of products suitable for nutrition, namely, the energy content of produced milk occupies 78.9–82.8 % (350 cows) and 82.9–86.1 % (450 cows) in accordance with productivity, which is the determining factor of both the coefficient of energy efficiency of products suitable for

nutrition and total products.

4. Increasing the capacity of the enterprise by increasing the number of cows requires additional costs of total energy, depending on their productivity level of 7000 kg; 8000 kg; 9000 kg at the level of 428.3 GJ/head; 462.8 GJ/head and 500.3 GJ/head, respectively. There is no significant difference in the structure of energy costs.

5. Within the parameters of the enterprise of one standard size of average capacity per 1 cow, the total energy costs for 7000 kg and 8000 kg are 443 and 478 GJ (350 cows), respectively; 441 and 476 GJ (400 cows) and 440 and 474 GJ (450 cows), that is, they are slightly reduced if the number of cows changes from 350 to 450 heads – by 0.7% if the milk yield increases to 9000 kg – reduction costs increased by 0.6 % – 515 GJ (350 cows) against 512 GJ (450 cows).

6. Increasing the productivity of cows from 7000 kg to 9000 kg requires additional total energy costs in the amount of 16.3–16.4% to the base level, regardless of the standard size, which corresponds to 0.036 GJ of total energy per 1 kg of added milk.

7. It is established that the coefficient of energy efficiency of products suitable for nutrition under conditions of increasing productivity of cows from 7000 kg to 9000 kg within each standard size improves from 5.45% to 6.14 % (350 cows), from 5.49% to 6.18 % (450 cows), but practically does not increase when it changes. The coefficient of energy efficiency of total products, respectively, the standard size and productivity level of cows is at the level of 25.6% -26.6% and 25.8–26.7%, that is, it also maintains a similar trend.

8. Regularities of the influence of changes in the quality characteristics of products on the energy consumption of their production are established. Thus, within the productivity range from 7,000 kg to 9,000 kg of milk per cow per year, an increase in the fat content in milk by 0.1% improves the energy efficiency coefficients by 0.06-0.07 %.

9. A systematic approach based on which an algorithm for calculating the main elements of competitiveness of an enterprise of average production capacity is created in the MS Excel environment, combining a margin assessment of its activities by types of energy consumption within the established technical and production indicators depending on changes in the energy efficiency of beef and milk production and its primary qualitative characteristic-fat.

10. Within the parameters of the simulation model, the assessment of existing technologies, taking into account the costs of total energy for the production of products in accordance with its energy content, allows us to determine the energy component of each type of resource and, based on their availability, form the most efficient production process in terms of energy efficiency and make operational decisions on its practical improvement.

References

Gadzalo, Y. M., Baschenko, M. I., Zhuk, V. M., & Lupenko, Y. O. (Eds.). (2016). Strategy for the development of agricultural production in Ukraine until 2025. Kyiv: Agrarian Science. 216 p.

Baschenko, M. I. (Ed.). (2017). Animal husbandry in Ukraine: State, problems, and development prospects (1991–2017–2030). Kyiv: Agrarian Science. 160 p.

Vedmedenko, O. V., & Kovalenko, V. V. (2020). Current state of the cattle breeding industry in Ukraine. In Modern science: State and prospects for development in agriculture: Proceedings of the II All-Ukrainian Scientific and Practical Conference of Young Scientists on the occasion of Science Day, November 10, 2020 (pp. 92–96). Kherson.

Rudenko, Y. V., et al. (2017). Technical and economic parameters and planning solutions

for the reconstruction and new construction of dairy farms: Reference book (2nd ed., revised and expanded). Kharkiv: Institute of Animal Husbandry, NAAS. 370 p.

Institute of Animal Husbandry, UAAS. (2008). Annual standards for feed procurement and structure for different types of animals depending on their productivity across Ukraine's zones: Normative scientific and production guide (3rd ed., expanded). Kharkiv. 31 p.

Marchenko, V. A., Korkh, I. V., Korkh, O. V., Petrash, V. S., Admin, O. Y., Admina, N. G., & Tkachov, A. V. (2020). Improving the efficiency of attracting investments for farms with varying annual milk production volumes: Recommendations. Kharkiv: Institute of Animal Husbandry, NAAS. 45 p.

Getmanets, O. M. (2012). Econometrics: Lecture course for students of the Faculty of Management, studying in the direction of training 6.030601 – "Management". Kharkiv: Kharkiv State Zooveterinary Academy, RIO KhSZVA. 94 p.

Baranovsky, D. I., Getmanets, O. M., & Khokhlov, A. M. (2017). Biometry in the MS Excel software environment: Textbook. Kharkiv: SPD FO Brovin O.V. 90 p.

State Statistics Service of Ukraine. (2023). Animal husbandry in Ukraine 2022. Kyiv. 158 p.

Kulyk, M. F., et al. (1997). Methodology for bioenergy assessment of livestock and feed production technologies. Vinnytsia. 54 p.

Marchenko, V. A., Korkh, I. V., Petrash, V. S., & Tkachov, A. V. (2019). Justification of mechanisms for optimizing technological and economic parameters of dairy farms and complexes of varying production capacities. Bulletin of Sumy National Agrarian University. Livestock Series, 1–2(36–37), 70–78. https://doi.org/10.32845/bsnau.lvst.2019.1-2.12

Marchenko, V. A., Trishyn, O. K., Chygrynov, Y. I., Drozdov, S. Y., Petrash, V. S., Tkachov, A. V., & Ponomarova, V. V. (2023). Energy efficiency of cattle breeding production in small enterprises within the system of technological and technical solution parameters and standards. Scientific Progress & Innovations, 26(2), 72–78. DOI: https://doi.org/10.31210/spi2023.26.02.13 UDC 636.2.034

Marchenko, V. A., Trishyn, O. K., Chygrynov, Y. I., Drozdov, S. Y., Petrash, V. S., Admina, N. G., Tkachov, A. V., & Ponomarova, V. V. (2023). Features of forming a system of parameters and standards for technological and technical solutions in the creation of small-capacity enterprises. Scientific and Technical Bulletin of the Institute of Animal Husbandry, NAAS, (129), 130–140. DOI: https://doi.org/10.32900/2312-8402-2022-128-130-140

Busenko, O. T., et al. (2005). Technology of livestock production. Kyiv: Higher Education. 496 p.

State Committee of Ukraine for Urban Planning and Architecture. (1995). DBN V.2.2–1–95 "Buildings and structures for animal husbandry". Kyiv. URL: https://ips.ligazakon.net/document/

Ibatullin, I. I., & Zhukorsky, O. M. (Eds.). (2016). Guide to complete feeding of farm animals: Reference book. Kyiv: Agrarian Science. 336 p.

Bogdanov, G. O., & Kandyba, V. M. (Eds.). (2012). Standards and rations for complete feeding of high-yielding cattle: Reference book. Kyiv: Agrarian Science. 296 p.

Pankeev, S. P. (2022). Technological features of beef production in agricultural enterprises of the Kherson region. Tavria Scientific Bulletin, (124), 174–182. DOI: https://doi.org/10.32851/2226-0099.2022.124.24

Kostenko, O. I., & Kravchenko, O. V. (2019). Energy efficiency of milk production technologies in medium-sized agricultural enterprises in Ukraine. Bulletin of

Agrarian Science, 97(10), 45–52. DOI: 10.31073/agrovisnyk201910-07

Petrenko, S. M., & Syrotyuk, I. P. (2021). Modeling of energy-saving technologies in animal husbandry: Approaches to optimizing production at medium-sized farms. Technology and Techniques of APK, 8(32), 18–25.