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

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*The results of generalized data on various technologies of large-scale enterprises with milk production volumes (more than 40 thousand c/year) and a cow population of more than 500 heads are presented. Various milking technologies with milk productivity of cows up to 6000 kg, from 6000 kg to 7000 kg and more than 7000 kg of milk per cow are analyzed, options for using additional technical means for preparing and distributing Feed, distribution of cows according to feeding technologies – the ratio correlates with the system of maintenance, but the type of feeding also depends more on the feed supply sector, on this basis the elements of production technologies (milk, beef from culled cattle, increase in live weight of animals on cultivation, fattening) are justified, which are characteristic of the rational organization of the process.*

*The created simulation model of production of cattle products within certain parameters of enterprises of large production capacity is applied – with the number of cattle 2500-3200 heads, (600-1000 cows with a capacity of 7000-9000 kg per cow and the fat content of milk 3.8-4.1 %).*

*The structure of the energy content of products by type is determined and given - milk, live weight of culled animals, growth of raised livestock, obtained offspring, taking into account the energy content of excrement and litter. It is proved that the largest share in the structure of the energy content of products suitable for nutrition belongs to the energy content of produced milk – 76.1–84.4 %., In relation to this most influential factor on the coefficients of energy efficiency of the main and total production, 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. The determination of annual total energy costs for the production of cattle products is carried out taking into account the logistics component of the technological process.*

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

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

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*Представлені результати узагальнених даних різних технологій великотоварних підприємств з обсягами виробництва молока (більше 40 тис. ц/рік) і поголів'ям корів більше 500 голів. Проаналізовано різні технології доїння із молочною продуктивністю корів до 6000 кг, від 6000 кг до 7000 кг і більше 7000 кг молока на корову, варіанти застосування додаткових технічних засобів з підготовки та роздавання кормів, розподіл корів за технологіями годівлі – співвідношення корелює із системою утримання, але тип годівлі більше залежить також від сектору кормозабезпечення, На цій основі обґрунтовані елементи технологій виробництва продукції (молока, яловичини від вибракуваної худоби, приросту живої маси тварин на вирощуванні, відгодівлі), що властиві раціональній організації процесу.*

*Застосовано створену імітаційну модель виробництва продукції скотарства в межах визначених параметрів підприємств великої виробничої потужності – з чисельністю поголів'я великої рогатої худоби 2500-3200 голів, (600-1000 корів із продуктивністю 7000-9000 кг на корову і вмістом жиру молока 3,8-4,1 %).*

*Визначено і наведено структуру енерговмісту продукції за видами - молоко, жива маса вибракуваних тварин, приріст худоби, що вирощуються, отриманого приплоду з урахуванням енерговмісту екскрементів і підстилки. Доведено, що найбільша частка в структурі енерговмісту продукції, придатної для харчування належить енерговмісту виробленого молока – 76,1–84,4 %., Відносно цього найбільш впливового на коефіцієнти енергетичної ефективності основної і загальної продукції чинника визначені функціональні залежності енерговмісту продукції від жиру в молоці та взаємозв'язок коефіцієнтів енерговмісту продукції і жиру молока. Визначення річних загальних затрат сукупної енергії на виробництво продукції скотарства проведено з урахуванням логістичної складової технологічного процесу.*

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

Modern conditions for the functioning of various types of agricultural enterprises require compliance with a clear algorithm for the functioning of all parts of the production process mechanism (Gadzalo et al., 2016; Baschenko et al., 2017; Vedmedenko & Kovalenko, 2020).

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).

With increasing capacity to the conditions of large-scale production (due to increased productivity, territorial expansion or application of more effective organizational or technological solutions) compliance with the laws of energy efficiency formation of technological processes for the production of high-quality livestock products in conditions of restriction of various types of resources becomes a determining element of competitiveness and therefore clarification of the features of the formation of a system of parameters and justification of standards of technological and technical solutions when creating enterprises of this type is particularly important and relevant.

Previous studies of milk production technologies for small (with a population of 20-150 cows) and medium (350-450 cows) farms allowed us to justify a systematic approach based on which an algorithm for calculating the main elements of energy consumption of resources of such enterprises was created in the MS Excel environment (Marchenko et al., 2020; Getmanets, 2012).. The implementation of a margin assessment of various options for types of energy consumption within the established technical and production parameters allowed us to quantify the coefficients of energy efficiency of products suitable for nutrition and the coefficients of energy efficiency of total products for cow productivity from 7000 kg to 9000 kg within each standard size, taking into account the qualitative characteristic-milk fat. It is based on pilot projects of enterprises developed on the basis of reasonable organizational and production parameters in conditions of fixed high (8000 kg of milk per cow per year) productivity. It should be noted that in the conditions of martial law and the deterioration of many social conditions in rural areas and under the influence of actual climate changes, the assessment of the effectiveness of technological solutions from an economic point of view becomes limited because it does not take into account the component of energy efficiency of production and especially taking into account the quality of raw materials or finished products. Among the many technological solutions in the conditions of today, the creation and maintenance of an efficient production structure is a difficult but relevant task at any stage, 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.

Increasing the capacity of enterprises increases the negative pressure on the environment and therefore it is very important to reduce the harmfulness of various types of emissions, preserve soil fertility, which indirectly affect changes in climatic conditions. At the same time, the management of these factors in the technological process as a whole changes the energy efficiency of cattle production. (Rudenko et al., 2008; Rudenko et al., 2017; Marchenko et al., 2020; Marchenko et al., 2023; Busenko, 2005).

Previous developments of milk production technologies for large-scale enterprises (with a population of 1000 cows) made it possible to justify their organizational, production and economic parameters under conditions of fixed high productivity (8000 kg of milk per cow per year) (Getmanets, 2012; Baranovsky et al., 2017).. Prior to this, consumption standards were defined separately and patterns of their changes were established under conditions of different productivity of cows (from 4000 to 9000 kg of milk per year). Modern realities require rationalization of such solutions 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)..

According to statistics, among 1,533 enterprises, only 275 (17.8% of the total number) keep 1,000 or more heads of cattle, and their share in the total structure of the cattle population reaches 61.9 %. Currently, among the total number of 1,440 enterprises with a population of more than 1,000 cows, only 74 enterprises (5.1%), the same share not only accounts for almost a third of the population – 30.3%, but is also characterized by higher animal productivity (Tvarinnitstvo, 2023). However, not all technologies or their individual elements used by such enterprises meet modern requirements and therefore they need to be improved to improve (Kostenko et al., 2010; Kostenko, 2018).

At the same time, 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; DBN V. 2.2-1-95, 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 a positive environmental impact.

Directions for further improvement and principles of building basic technological processes in the production of cattle breeding products for large-scale 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).

The object of the study was selected agricultural enterprises for the production of high-capacity milk with a cow population of at least 500 heads.

The purpose of the research is to find out the specifics of forming a system of parameters and standards of technological and technical solutions when creating large-capacity enterprises

**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.** Systematization and generalization of technological and technical solutions of large-capacity Enterprises made it possible to use reporting forms No. 50 – SG, technological passports for the production of dairy cattle farms, which are classified as large-scale enterprises by the volume of milk production (more than 40 thousand c/year) and the number of cows (more than 500 heads) - SE "DG "Artemida" IC Naas of Ukraine", SE "DG Institute of Agriculture of the north-east of the Naas, SE "DG "Gontareva" it Naas, as well as fragments of the agricultural holding "Astarta". The analysis of the livestock structure in Ukraine is made. which shows that over the past ten years, the share of cows in all types of enterprises relative to the total number of cattle has increased to 58.6% compared to 33.8% in 1990. (Astarta – 53.1%). (Marchenko, 2020; Tvarinnitstvo, 2023). The productivity of cows determined by the method of grouping by types of enterprises allowed us to establish approximate volumes of milk production in gradations of different standard sizes, and the generalization of statistical reporting data for the last three years showed that they are distributed according to the number of cows and milk production as follows (table. 1).

*Table 1*

**Grouping businesses by the number of cows**

| Indicators | Dairy Cow Farms | | cows | | gross milk yield | |
|---|---|---|---|---|---|---|
| | n | % | thousand heads | % | thousand tons | % |
| Dairy Cow Farms | 1440 | 100,0 | 394,2 | 100,0 | 2606,1 | 100,0 |
| including heads: up to: 50 | 403 | 28,0 | 8,3 | 2,1 | 30,8 | 1,2 |
| 50 – 99 | 209 | 14,5 | 15,7 | 4,0 | 73,4 | 2,8 |
| 100 – 499 | 614 | 42,7 | 157,5 | 40,0 | 1005,9 | 38,6 |
| 500 – 999 | 140 | 9,7 | 93,1 | 23,6 | 612,3 | 23,5 |
| more than 1000 | 74 | 5,1 | 119,6 | 30,3 | 883,7 | 33,9 |

So, large-scale enterprises, provided that their share of the total number is only 14.8%, have the potential of cows at the level of 212.7 thousand heads, which is 53.9% of their total number of 394.2 thousand heads, and milk production – at the level of 1496 thousand tons or 57.4%.

It is established that in the farms that were included in the monitoring of the development of a program for technological re-equipment of the dairy cattle industry of state-owned enterprises of experimental farms of the Naas network, the milk productivity of cows largely depends on the cow maintenance system and related technology features. The share of cows that were kept using the advanced technology of loose keeping using boxes and on deep bedding was 22%, and the rest of the livestock is kept on a leash. Among large-scale enterprises, the distribution of cows by keeping systems with innovative elements of technological solutions has new or reconstructed premises for loose maintenance (box, deep bedding). this share increases to 28-30%. Productivity ranges from 4852 kg to 7962 kg (at the moment there are more – 8100-8700 kg).

According to the generalized data, there is an advantage in the productivity of cows in the case of using the system of loose keeping and milking in the milking parlor – up to 1.2–1.4 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 6000 kg, from 6000 kg to 7000 kg and more than 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). The ratio correlates with the maintenance system, but this type of feeding also depends more on the feed supply sector, under the conditions of using the services of the feed Center (example of Astarta enterprises) and feeding according to modern requirements of balancing the feed mixture (according to the productivity of cows), the annual yield of different productive technological groups is at the level of at least 7000 kg per cow with an interval of annual productivity of at least 1000 kg. An influential factor in the productivity of cows and their growth is the problem with reproduction using any technology, as indicated by the significant variability in the yield of calves per 100 cows-from 51 to 97%.

Studies have shown that a separate element of the technological process is the logistics component, which in the conditions of a large-scale enterprise requires additional corresponding costs for its functioning. Transportation costs vary depending on the distance of production facilities from each other, and also depend on the sales channel of products. At the same time, such a structural unit has all the advantages within the feed delivery shoulder (no more than 70 km) by providing better feeding of animals. In the developed simulation model of enterprise technology variants, which will be discussed below, all calculations of energy costs are carried out taking into account the logistics component for the sale of products within the delivery shoulder of 50 km.

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

Taking into account the high variability of cow productivity indicators in the first approximation to the system of parameters and standards of technological and technical solutions, three variants of the standard size were selected – 600, 800 and 1000 cows with full herd turnover and uniform production of marketable products. Annual productivity in the range of 7000-9000 kg of milk per cow. The marketability of milk is 94 %.

Under these conditions, the calculated volumes of feed supply within the average annual number of cows (600-1000 heads) and their annual productivity (7000-9000 kg/head) make it possible to obtain an annual shaft of milk of 4200-9000 tons. Taking into account its drinking to calves, the size of milk sales will be 3950-8460 tons.

Herd structure – cows-31.3 – 33.8 %; heifers-5.9 – 6.1 %; heifers older than one year-13.8 – 17.7 %; heifers up to one year-17.6 – 18.1%; bitches older than one year–9.7 – 9.9%, bitches up to one year–17.8-18.1%. Rejection and replacement of the main herd – 20-25 % (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 %.

The calculations take into account the products in live weight from culled and fattened livestock in accordance with the structure and turnover of the herd. The feed supply of the cattle herd is based on a system of the same type of feeding with feed mixtures.

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-680-730 kWh. Energy equivalents of other resources-according to certain or known reference values (Rudenko et al., 2008; Kulik, 1997).

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, the share of grain accounts for no more than 80% and 20% are additives (annual standards for harvesting and feed structures for different types of animals, depending on their productivity in the zones of Ukraine: normative scientific and production manual, 2008).

Practical experience in the operation of cattle farms proves that the achievement of design indicators of production and productivity of livestock, first of all, is limited by the feed availability and usefulness of animal feeding. In this regard, in practice, there is a need to review the traditional systems of production, harvesting and use of feed, when the production of dairy cattle products should ensure full and uniform feeding of animals throughout the year. It is necessary to take into account the effect of logistics factors of mutual distance between individual links of the technological cycle: cultivation of forage crops by type in crop rotations, places and volumes of storage facilities, as well as resources for feed preparation and delivery of feed mixtures to animals. Thus, in feed production: increasing feed supply, increasing the volume and increasing the efficiency of cattle production contributes to: growing the highest-yielding forage crops; harvesting them in the phases of maximum accumulation of nutrients; preparation of high-quality silage, haylage, hay, which in combination with concentrates form the basis of diets of cows and young animals throughout the year;

Calculations of technology variants made it possible to determine the energy efficiency of cattle production of regulated quality in the conditions of large-capacity enterprises within the parameters of technological solutions. Options are considered for enterprises with an average annual number of cattle of 2500-3200 heads. Annual total energy costs for production (milk, growth, Live weight) are set under conditions of varying annual productivity of cows from 7000 to 9000 kg/head.

According to the structure within the standard size of 600 cows (7000-9000 kg/head), the total total energy costs are as follows: 8.3–7.8 % – for herd reproduction, 1.8–1.6 % – from fixed assets of production, 3.7–3.4 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 2.3 – 2.0 %, the total energy converted in feed and litter is 83.9–85.2 %. It was found that for 600 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 11.8 % – from 240387 GJ to 268915 GJ (or from 445 GJ to 498 GJ per cow).

According to the structure within the standard size of 800 cows, the total total energy costs are as follows: 8.4–7.8 % – for herd reproduction, 1.6–1.4 % – from fixed assets of production, 3.7–3.3 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 1.8 – 1.6 %, the total energy converted in feed and litter is 84.5–85.9 %. With an increase in productivity in this case, the total and specific costs of total energy for production increase by 11.8% from 327960 GJ to 366764 GJ (or from 444 GJ to 497 GJ per cow).

According to the structure, within the standard size of 1000 cows, the total total energy costs are as follows: 8.5–7.9 % – for herd reproduction, 1.3–1.2 % – from fixed assets of production, 3.7–3.3 % – from working capital without feed and bedding. The total energy of direct and indirect labor costs is 1.3 – 1.2 %, the total energy converted in feed and litter is 85.2–86.4 %. For 1,000 cows with a plume with an increase in productivity by the same 28.6%, the total total energy consumption for production increases by 11.9% from 411,807 GJ to 460,886 GJ (or from 440 GJ to 490 GJ per cow).

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 increases from 15248 GJ to 18563 GJ for 600 cows and from 24889 GJ to 30635 GJ for 1000 cows or by 22-23 %. The largest share in the structure of the energy content of such products is occupied by the energy content of produced milk 76.1–84.4% in accordance with productivity, which becomes a determining factor, both the coefficient of energy efficiency of products suitable for nutrition and the total product (table. 2).

*Table 2*

**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 %) | 76,1–80,8 | 78,4–82,8 | 80,4–84,4 |
| live weight of culled animals | 10.0 | 9,0 | 8,2 |
| received for the year of offspring | 0.7–0,8 | 0,7 | 0.6 |
| weight gain of farmed animals | 13,2–8,4 | 11,9–7,5 | 10,8–6,8 |
| food-friendly products | 100 | 100 | 100 |

Created in the MS Excel environment, the calculation algorithm, which uses a set of initial conditions for the feasibility study of a large production capacity enterprise such as the turnover and structure of the herd, productivity by gender and age groups, costs by the structure of feed, material and other types of resources, etc., allowed us to conduct a margin analysis by types of energy consumption within the selected variants of technical and production parameters and determine the dependence of changes in the energy efficiency of production, taking into account the energy content of milk and its primary quality characteristics – Giroud (Merkurieva, 1980).

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 % (the content corresponds to the regulated quality of natural milk), it was determined that the coefficient of energy efficiency of products suitable for nutrition improves from 5.65–6.93% to 5.87–7.14 % (600 cows) and from 5.39–6.62% to 5.62–6.91 %(1000 cows). The energy efficiency coefficient of total products increases from 26.1–27.1% to 26.4–27.4 % (600 cows) and from 26.2–27.1% to 26.4–27.4% (1000 cows), respectively. Thus, it is proved that both coefficients improve in the case of an increase in productivity and fat content of milk (improvement in quality according to this indicator), which generally gives a positive result within the studied gradations of parameters. Patterns of changes reflect graphical dependencies in figures 1-6.

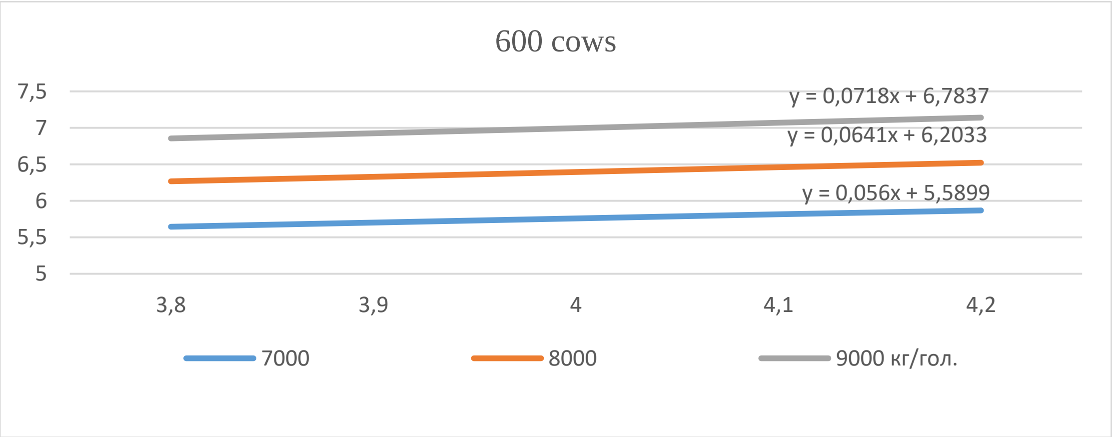


*Fig. 1* **Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.**

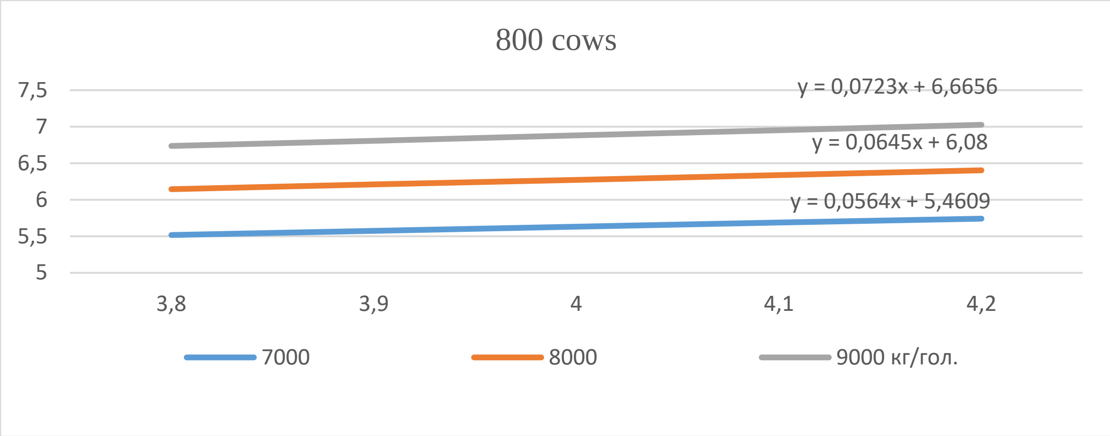


*Fig. 2.* **Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.**

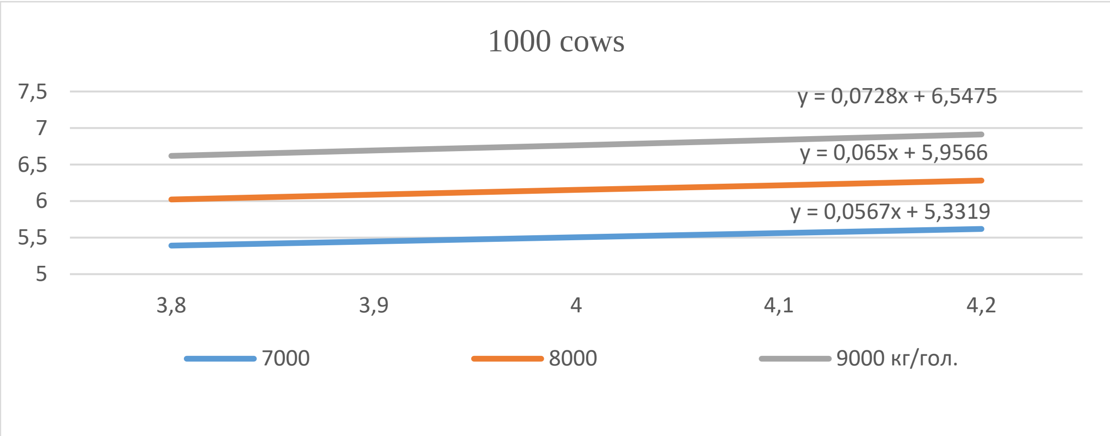


*Fig. 3.* **Dependence of the energy efficiency coefficient of products suitable for nutrition on the fat content in milk and productivity of cows.**

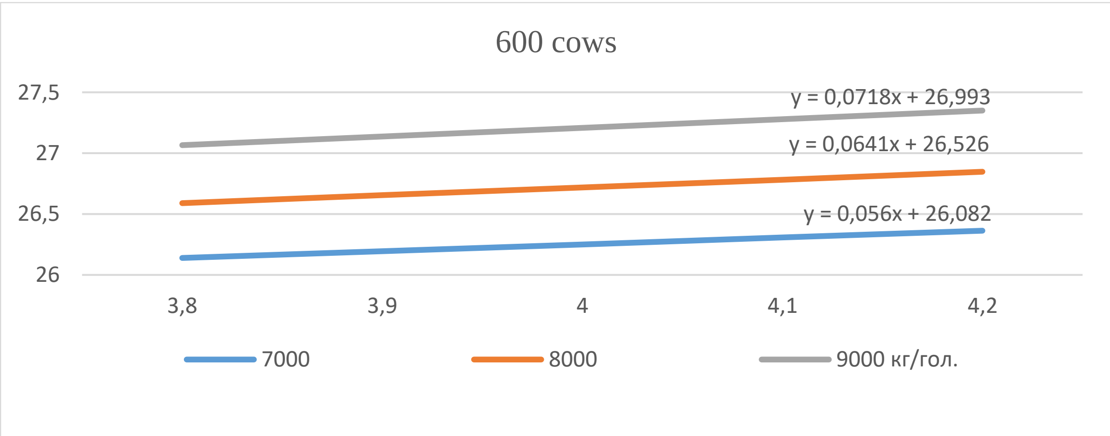


*Fig. 4.* **Dependence of the energy efficiency coefficient of total production on the fat content in milk and productivity of cows.**

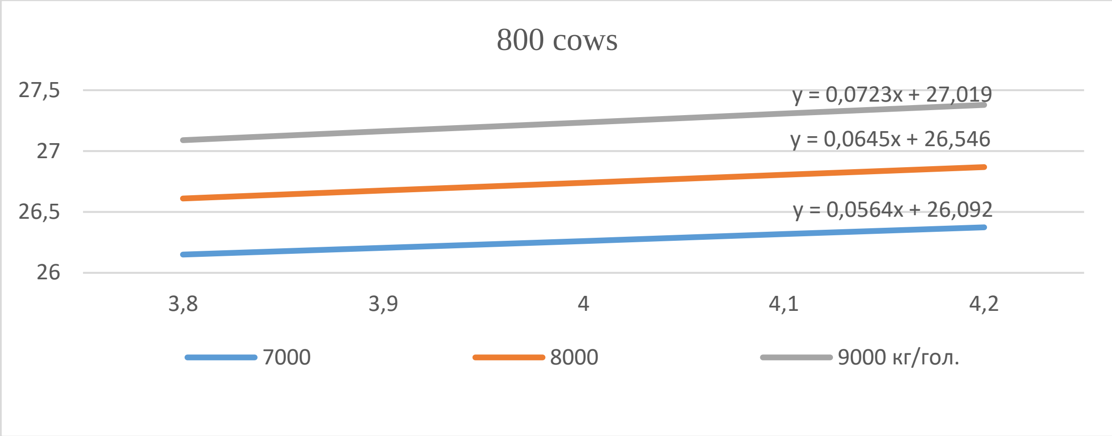


*Fig. 5.* **Dependence of the energy efficiency coefficient of total production on the fat content in milk and productivity of cows.**

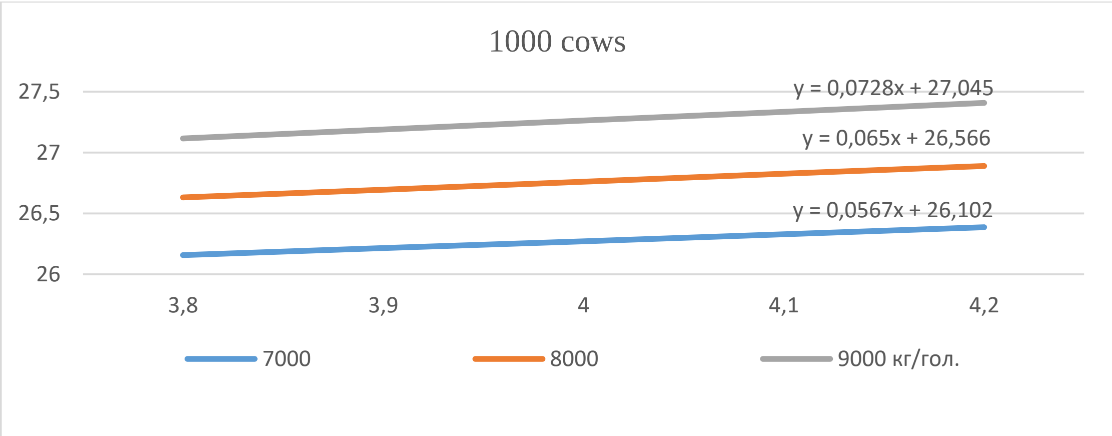


*Fig. 6.* **Dependence of the energy efficiency coefficient of total production on the fat content in milk and productivity of cows.**

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 are shown in figures 7-12.

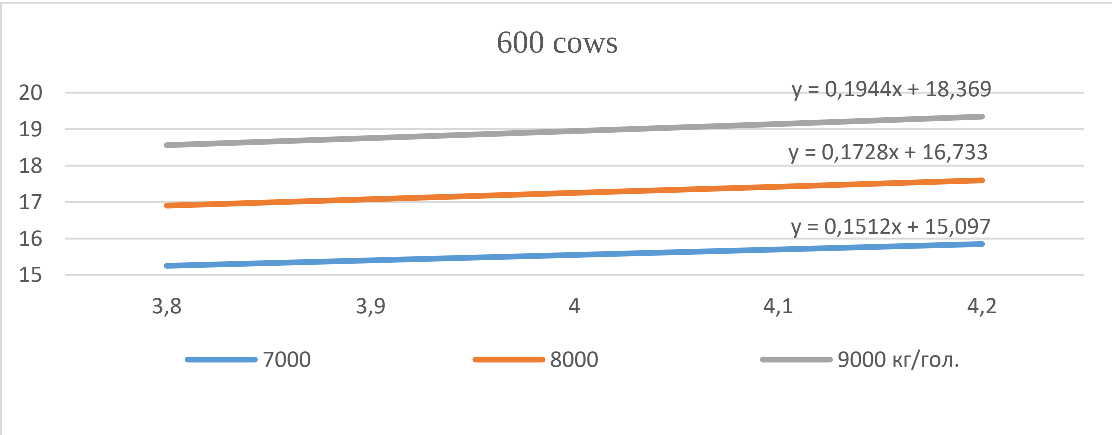


*Fig. 7.* **Dependence of the energy content of products suitable for nutrition (thousand GJ) on the fat content in milk and productivity of cows.**

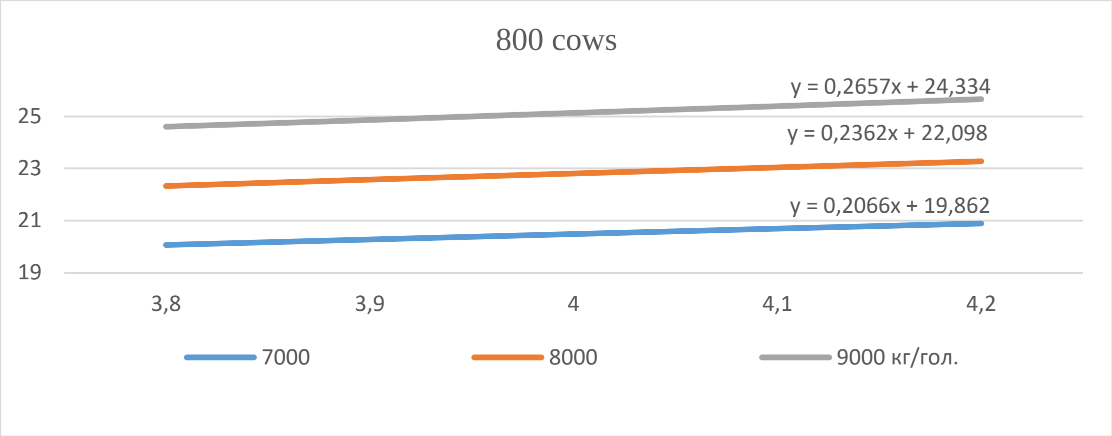


*Fig. 8.* **Dependence of the energy content of products suitable for nutrition (thousand GJ) on the fat content in milk and productivity of cows.**

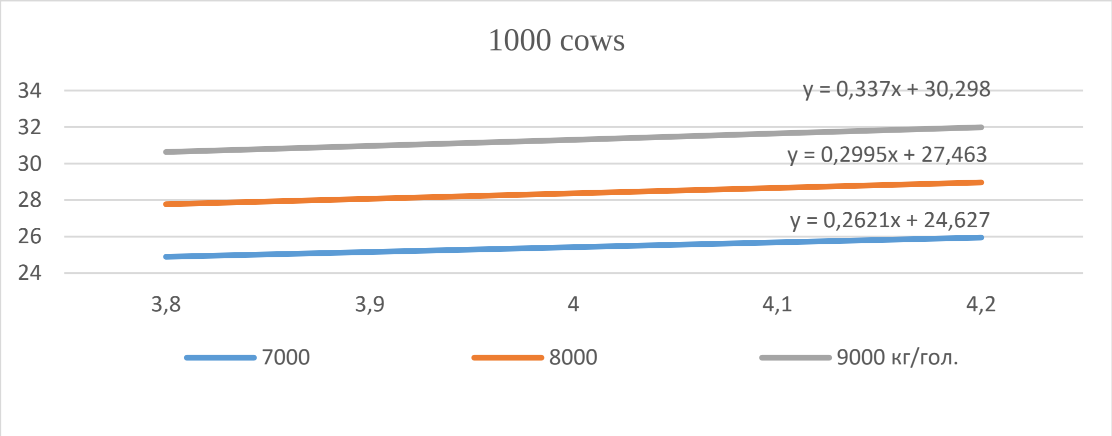


*Fig. 9.* **Dependence of the energy content of products suitable for nutrition (thousand GJ) on the fat content in milk and productivity of cows.**

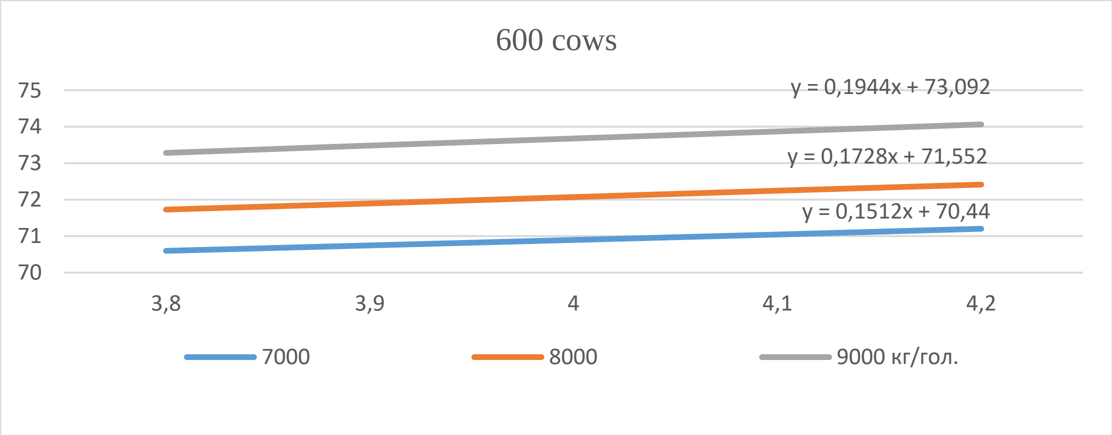


*Fig. 10.* **Dependence of the energy content of all products, taking into account conjugate (thousand GJ), on the fat content in milk and cow productivity.**

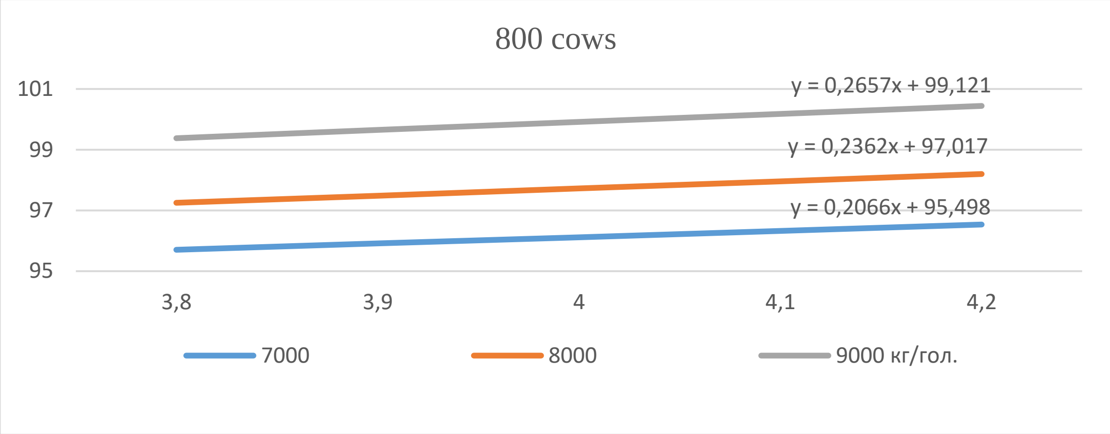


Fig. 11. **Dependence of the energy content of all products, taking into account conjugate (thousand GJ), on the fat content in milk and cow productivity.**

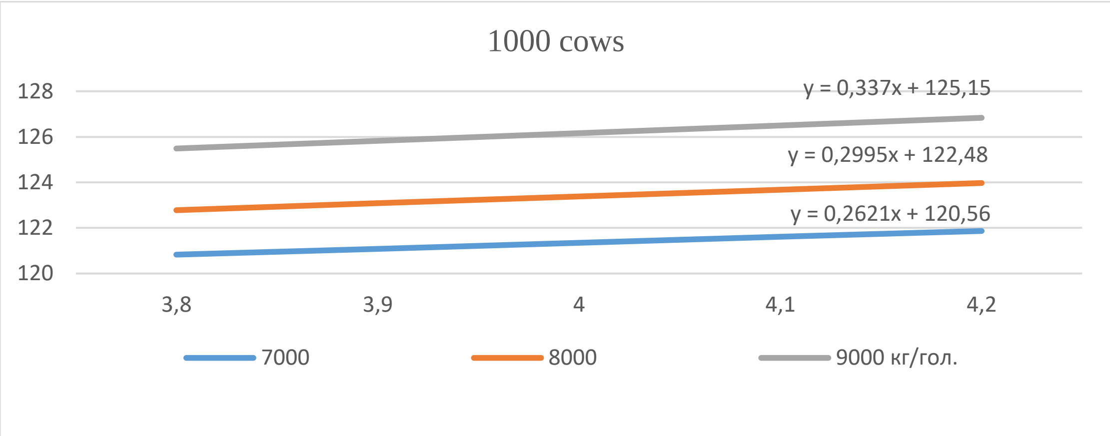


*Fig. 12.* **Dependence of the energy content of all products, taking into account conjugate (thousand GJ), on the fat content in milk and cow productivity.**

These dependencies confirm the opinion that regardless of the fat content in milk, with an increase in productivity, both the energy content of products suitable for nutrition and the energy content of all products increase. 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 of milk is an increase in this energy content by 1658-1744 GJ (600 cows) , 2266-2384 GJ (800 cows), 2873-3023 GJ (1000 cows) or within 5.2% in accordance with the quality of milk in terms of fat content. The increase in the energy content of all products from increasing the productivity of cows (600 heads) from 7000 kg to 8000 kg is 1134-1220 GJ (7.6 %), from 8000 kg to 9000 kg – 1561-1648 GJ (5.6 %).

For 800 cows, there is an increase of 1548-1666 GJ (7.6 %) and 2134-2252 GJ (5.5%), for 1000 cows, the trend continues – 1962-2112 GJ (7.6 %) and 2706-2856 GJ (5.4%), respectively.

The dependences of changes in the energy content of products suitable for nutrition and the energy content of all products on the fat content of milk are shown in Tables 3 and 4.

*Table 3*

**Relationship between the energy content of food-friendly products (Y), % from milk fat content (X), %**

| Milk fat content (X), % | number of cows, heads | | |
|---|---|---|---|
| | 600 | 800 | 1000 |
| 3,8 | y = 1,6577x + 13,59 | y = 2,2654x + 17,803 | y = 2,8732x + 22,016 |
| 3,9 | y = 1,6793x + 13,720 | y = 2,295x + 17,980 | y = 2,9106x + 22,241 |
| 4,0 | y = 1,7009x + 13,849 | y = 2,3245x + 18,157 | y = 2,948x + 22,465 |
| 4,1 | y = 1,7225x + 13,979 | y = 2,354x + 18,334 | y = 2,9855x + 22,69 |
| 4,2 | y = 1,7441x + 14,108 | y = 2,3835x + 18,511 | y = 3,0229x + 22,915 |

*Table 4*

**Relationship of energy content of all products (Y), % from milk fat content (X), %**

| Milk fat content (X), % | number of cows, heads | | |
|---|---|---|---|
| | 600 | 800 | 1000 |
| 3,8 | y = 1,3475x + 69,172 | y = 1,8408x + 93,767 | y = 2,3341x + 118,36 |
| 3,9 | y = 1,3691x + 69,302 | y = 1,8703x + 93,944 | y = 2,3716x + 118,59 |
| 4,0 | y = 1,3907x + 69,431 | y = 1,8998x + 94,121 | y = 2,409x + 118,81 |
| 4,1 | y = 1,4123x + 69,561 | y = 1,9294x + 94,298 | y = 2,4464x + 119,03 |
| 4,2 | y = 1,4339x + 69,691 | y = 1,9589x + 94,475 | y = 2,4839x + 119,26 |

The dependences of changes in the coefficients of energy efficiency of products suitable for nutrition and total products, respectively, the qualitative characteristics of milk in the dynamics of productivity growth of cows (7000-9000 kg/head) within the standard sizes of enterprises (600: 800 and 1000 cows) are illustrated in Tables 5 and 6.

*Table 5*

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

| Milk fat content (X), % | number of cows, heads | | |
|---|---|---|---|
| | 600 | 800 | 1000 |
| 3,8 | y = 0,6048x + 5,0467 | y = 0,6103x + 4,9126 | y = 0,6158x + 4,7786 |
| 3,9 | y = 0,6127x + 5,0948 | y = 0,6183x + 4,9611 | y = 0,6238x + 4,8274 |
| 4,0 | y = 0,6206x + 5,1429 | y = 0,6262x + 5,0095 | y = 0,6319x + 4,8761 |
| 4,1 | y = 0,6285x + 5,1911 | y = 0,6342x + 5,058 | y = 0,6399x + 4,9249 |
| 4,2 | y = 0,6364x + 5,2392 | y = 0,6422x + 5,1064 | y = 0,6479x + 4,9737 |

*Table 6*

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

| Milk fat content (X), % | Number of cows, heads | | |
|---|---|---|---|
| | 600 | 800 | 1000 |
| 3,8 | y = 0,4634x + 25,671 | y = 0,4715x + 25,674 | y = 0,4797x + 25,676 |
| 3,9 | y = 0,4713x + 25,719 | y = 0,4795x + 25,722 | y = 0,4877x + 25,725 |
| 4,0 | y = 0,4792x + 25,767 | y = 0,4875x + 25,771 | y = 0,4958x + 25,774 |
| 4,1 | y = 0,4871x + 25,816 | y = 0,4954x + 25,819 | y = 0,5038x + 25,823 |
| 4,2 | y = 0,495x + 25,864 | y = 0,5034x + 25,868 | y = 0,5119x + 25,871 |

Thus, calculations indicate that both an increase in productivity and an improvement in milk quality have a positive effect on the energy efficiency of production in relative terms. The substantiated dependencies and established regularities make it possible to practically quantify the efficiency of costs from an energy point of view in the conditions of various technologies for the production of cattle products.

**Discussion.** In today's difficult conditions of limited various types of resources, their effective use for the production of cattle products, and especially in large-scale enterprises with an extensive network of technological elements, becomes of great importance. Many scientists-researchers and practitioners agree with the relevance of this complex problem today. In this sense, the materials of our research are aimed at revealing and deepening options for solving a number of complex problems of rational energy use. The purpose of the work coincides with general challenges caused by complications of production processes, such as a reduction in total production for various reasons, unfavorable climatic conditions, martial law. In the context of these policies, it should be added 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, and this, in turn, in the strategic perspective does not fully (indirectly) describe the characteristics of energy costs of resources. In these circumstances, it is more adequate, in our opinion, to apply energy assessment with the ability to determine and predict resource requirements through natural indicators of parameters and standards of the created or existing 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 large production capacity allowed to analyze the systems of keeping animals, the relationship of the degree of technical support for the production process of milk production, to establish inhibitory or contributing factors of influence, to create a simulation model, to determine the initial parameters. Within the specified parameters of the complex multi-factor simulation model of a large-scale enterprise, calculations are made and regularities of energy efficiency formation are established, which are illustrated by the presented materials.

The substantiated dependencies and established regularities make it possible, taking into account the qualitative characteristics of products, to form the main technological elements of the cattle production system within the parameters of enterprises of the standard size of 600-1000 cows with full herd turnover. Modeling of production using equations of dependence of its energy content on qualitative characteristics makes it possible to quantify the energy component of individual technological processes of production by types of resources and take the necessary measures to improve it.

**Conclusions:**

1. Monitoring and analysis of technological and technical solutions of enterprises of large production capacity, which showed the best results in terms of milk productivity in the conditions of various technologies of keeping, milking systems, feeding cows, the intensity of rearing young animals allowed to justify the initial parameters and standards of technological solutions and on this basis to assess the energy consumption and energy efficiency of cattle production.

2. In the system of parameters of the created complex simulation models, the dependencies of energy consumption formation on the main elements of resource support for the technological process of cattle production within the limits of changes in gradations of quantitative and qualitative characteristics – enterprise capacity, animal productivity, milk fat content-are justified.

3. The tools of simulation models and certain relationships allow you to directly simulate technological conditions, evaluate not only the quantitative energy component in accordance with each type of resources spent, but also, according to their availability, in fact, form the most energy-efficient technological process for the production of cattle products or improve it,

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