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# Х А Б А Р Л А Р Ы

# ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
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# SYSTEMS FOR MONITORING THE PRODUCTIVITY OF DAIRY FARM ANIMALS

**Abstract.** The relevance of this project lies in the fact that the use of modern digital, informational and intelligent technologies makes it possible to keep records of dairy productivity quickly and to respond to changes in the health of livestock in a timely manner. The result will increase the efficiency of resource potential use, as well as profitability and attractiveness of dairy cattle breeding for investors. The systems developed will also enable agricultural producers to make concrete decisions based on automated data analysis. The high quality of milk in the dairy farming industry, taking into account the feedback from the household to the consumer, ensures the competitiveness in the direction of the dairy industry. The article describes in detail a mathematical model for automating on-farm production control of dairy products, which will have an impact on the leveling of the commodity market. Also there are described the results of implementation of already developed software products for accounting of animal status on dairy farms of Northern Kazakhstan. As a result, some recommendations for the use of the developed software are given. In this way detailed results have been described for each farm, indicating the characteristics and status of the farms to date. The results obtained will be studied and considered by farmers at the local level to organise production processes. The implementation of this task will take place at the Seyfullin Kazakh Agrotechnical University. We have established a scientific group to develop and implement IT solutions for a large number of processes in agricultural production. This scientific programme is the first integrated solution aimed at introducing and adapting best practices in the application of digital technologies in dairy farming in Northern Kazakhstan.

**Key words:** expert system, data analysis, monitoring, milk yield, artificial intelligence, digital technologies, integration, diagnosis.

**Introduction.** The modern livestock industry in Kazakhstan is a transition to new approaches to production. It is based on agricultural machinery and equipment augmented with telemetry systems. Telemetry and monitoring systems for agricultural production are deemed as one of the most innovative technologies of precision livestock production and are automatic systems for collecting and transmitting information as well as data analysis and remote decision making [1].

There are many causes, which can be roughly divided into 'internal' and 'external', that have a major impact on cow yield. The 'internal' causes include: hereditary characteristics of the animal, its health and physiological condition; the 'external' causes include: quality and quantity of feed, length of pauses between milking of the animal and method of milking, number of years of cow's life, time between calves, length of fattening period. Common breaches of the accepted norms of cattle housing, untimely vaccination lead to disease, which can lead to the death of the herd in the future. In the case of infectious diseases there is also the potential for human infection [2].

In all of the above-mentioned livestock production processes, zootechnicians and veterinarians of livestock farms play a key and possibly important role, on whose expertise the productivity of livestock production and the economic component of the farm itself depends.

There has been an increase in the use of information technology in various sectors of the economy over the last decade. The development of cloud technology for data storage and processing, the ubiquity of mobile devices, smartphones and tablets, and IoT devices are creating new opportunities for the digitalisation of agriculture through automatic animal tracking and automatic control of production processes. The opportunities opened up by the development of IT technology require research and investigation into how it can be applied in livestock farming in practice.

Mathematical model used in an automated information system for the analysis and control of milk production. A mathematical model of changes in the productivity of a dairy cow by lactation periods has been developed. The model uses a function like:

$$y(t) = at^b e^{-ct}\ , \tag{1}$$

where is the rate of milk production in the animal's body at a time $t$, kg / day; $t$ - time, days; $a,b,c$ - options.

In this case, the milk yield in the time interval between the moments $t_{i-1}$ and $t_i$ is determined by integrating the function (1):

$$Y_i = \int_{t_{i-1}}^{t_i} y(t)dt, \tag{2}$$

where $Y_i$ is the productivity of the animal in the lactation time interval between the moments $t_{i-1}$ and $t_i$. The parameters $a,b,c$ are determined by the formulas:

$$c = r(t_m + t_f)/(t_m - t_f), \tag{3}$$

$$b = ct_m, \tag{4}$$

$$a = \frac{Y}{\int_{t-0}^{t-t_f} t^b e^{-ct}dt}, \tag{5}$$

The calculation of the parameters is based on the use of such characteristics of lactation as its duration $t_f$, annual milk yield $Y$, time to reach peak lactation $t_m$, as well as the average relative rate of decline in productivity after reaching the peak of milk yield $r$.

We will illustrate the use of function (1) for approximating the lactation curve using the example of one of the basic farms.

The farm contains Holstein cows. The milk yield of animals in January calving is 8260 kg / head, the duration of lactation is 305 days, the moment of reaching the peak lactation is on average the 90th day, the milk yield in the first days is 12 kg / head, on peak days - 50 kg / head, in the last days - 12 kg / bird, in the sixth month (on average - 168th day) of lactation - 35 kg / bird, in the eighth month (on average - 228th day) - 18 kg / bird. Then, the coefficient $k$=-0,0110829 is the relative rate of change in the level of the lactation curve $r$=-0,01102175; $a$=0,083954; $b$=1,822433364; $c$=0,02024926.

Thus, function (1) takes the following form:$y(t) = 0{,}083954t^{1{,}822433364}e^{-0{,}0202192}$.

By integrating function (1) over time, we obtain the distribution of the annual milk yield by months of lactation of the animal (for convenience, we will assume that the calving date is January 1): in January - 317 kg, February - 968 kg, March - 1471 kg, April - 1439 kg , May - 1279 kg, June - 967 kg, July - 734 kg, August - 512 kg, September - 336 kg, October - 236 kg; total - 8260 kg / head. Model calculations are easily automated in MS Excel environment.

The obtained mathematical model of the lactation process is used in planning milk yields and income from its sale in the context of the periods of the year and for the whole year, as well as the needs of animals for feed in different periods of the year.

Models have been developed for calculating the optimal duration of the productive life of an animal in the conditions of the farm and evaluating the effectiveness of decisions to renew the main herd. It has been established that the maximum average annual profit from the maintenance and use of animals should be taken as an optimality criterion. To calculate the total profit for T years of keeping animals, taking into account the time factor (the amount of discounted profit), you should use the formula:

$$P(T) = \sum_{t-1}^{T}(1+r)^{-t}(D(t) - Z(t) + (1+r)^{-T}S(T) - S(0)), \quad (6)$$

where *P(T)* is the total discounted profit from keeping a cow over the *T* years, tenge; *D(t)* - income from keeping a cow on the farm in the *i* year of lactation, tenge; *Z(t)* - expenses for keeping a cow in the *i* year of her productive life, tenge; *S(t)*- income from the sale of a cow after years of her stay in the herd, tenge; *r* - costs of replacing a cow left the herd (cost of a replacement heifer), tenge; - discount factor (usually corresponds to bank interest); *t* - current productive age of the cow, year.

Comparing *P(T)* different options for investment plans to choose the best one makes sense if projects with the same life cycle are considered. However, when we are faced with options that differ in the duration of their cycles, a different approach to solving the problem is required. A methodology for calculating and comparing alternative capital investment plans is needed, which would take into account both the time factor and the differences in the life cycle of the options under consideration, and the infinity of the planned horizon.

With regard to the conditions of our problem, these requirements are met by a methodology, the implementation of which involves calculations in two stages: using formula (1), the total discounted profit *P(T)* from the use of animals during the *T* years of productive life is calculated, *T*=1,2,…; for each variant of the duration of the economic use of the animal, the average annual profit $P_{av}(T)$ is determined, which is provided *P(T), T*=1,2,…, according to the formula:

$$P_{av}(T) = P(T)[r/(1 - 1/(1+r)^{T})], \quad (7)$$

Since, under the conditions of the problem under consideration, the minimum required return *r* on investment is the same for all possible options, the best of them will be the one that provides the maximum average annual profit $P_{av}(T)$ from the economic use of animals. Keeping an animal in a herd for more or less *T* years will reduce the value of the indicator under consideration.

Methodologically, a more correct solution of the problem involves taking into account the stochastic characteristics of the process under study: the probability distribution of mortality, unplanned culling of animals, offspring per 100 queens by years of productive life, and others. In this case, the calculation formula takes on a more complex form, and the task will be to maximize the value of the function:

$$P_{av}(T) = \frac{\sum_{t-1}^{T}(1+r)^{-t}ER(t)p(t-1)+(1+r)^{-T}S(T)(1-p_n(T))\prod_{t-1}^{T-1}p(t)-S(0)}{T}, \quad (8)$$

where $P_{av}(T)$ is the average annual profit from keeping a cow over the *T* years, tenge; *ER(t)* - expected profit from keeping a cow on the farm in the *i* year of her productive life, tenge; *p(t-1)* - the probability that the cow of the *(t-1)* productive age will move to the next, *t* age group. Wherein *p(0)=1*; *p(t)* - the probability that the cow of the *i* productive age will move to the next, *(t+1)* age group; $p_n(T)$ - the probability of the death of cows of the *T* productive age; *S(T)* - market value of a cow at the end of the *T* year of productive life, tenge; *S(0)*- market value of a heifer introduced into the main herd, tenge; *r* - discount factor (usually corresponds to the bank interest). Wherein,

$$ER(t) = P(t)p(t) + R(t)p_b(t) - S(0)(1 - p(t)), \quad (9)$$

where *P(t )*is the profit from keeping a cow on the farm in the *i* year of her productive life, tenge; *R(t)* - proceeds from the sale of a cow of the *i* age in the event of a production marriage (barrenness,

illness, low productivity), tenge; *S(0)*- the cost of a heifer introduced into the main herd instead of a cow retired at *t* age, tenge; $p_b(t)$ - the likelihood of unplanned culling of a cow due to a production defect in the *t* year; *t* - current productive age of the cow, year.

An econometric model of the movement of the market price for raw milk has been developed, which makes it possible to predict the price level in different periods of the year. The model is based on chain milk price indices. The model was tested on materials from the milk market of the Kostanay region (table 1).

Table 1 - Model parameters and their characteristics

| № | Variables | Coefficient | *t* -test |
|---|---|---|---|
| 1 | Free parameter | 1,033 | 137,28 |
| 2 | Trend | -0,00021 | 1,12 |
| 3 | February | - | - |
| 4 | March | - | - |
| 5 | April | -0.033 | 2.66 * |
| 6 | May | -0,051 | 4,13* |
| 7 | June | -0,037 | 2,97* |
| 8 | July | -0,032 | 2,60* |
| 9 | August | -0,024 | 1,97** |
| 10 | September | -0,015 | 1,19 |
| 11 | October | - | - |
| 12 | November | - | - |
| 13 | December | 0,018 | 1,46 |
| 14 | $R^2$ | 0,424 | - |
| 15 | *F*-test | 4,689 | - |
| * - significant at the level of 0.05; ** - significant at the 0.1 level. | | | |

The coefficient of determination is equal to 0.424, which indicates an acceptable predictive ability of the model. Accordingly, the correlation coefficient turns out to be 0.651; the relationship between the actual and calculated series of indices is quite strong. At the 0.05 level, the equation as a whole is significant. It has been established that in the dynamics of milk prices sold by agricultural entrepreneurs in Kostanay region, there is certainly a seasonality. Seasonality of prices is explained by the seasonality of production and supply of products to the market. Relatively low prices are observed during the "big milk" period from April to August-September. In turn, the season of large milk follows with a lag of 2-3 months after the period of mass calving (winter-first half of spring) on farms, especially in private farmsteads. Thus, the seasonality of production and prices for the products under consideration is decisively influenced by the fact that the overwhelming share in the total volume of milk supplies to the market is still occupied by personal subsidiary farms and small commercial enterprises (up to 80% or more). This situation will persist as long as the individual sector and small-scale production dominate in the industry's economy. And only with the development of intensive livestock raising should we expect the leveling of the product market [3].

**The results of the implementation of expert systems for monitoring the status of animals in dairy farms in Northern Kazakhstan.** The scientific research under the programme was organised in 6 model farms of Northern Kazakhstan: in farm No. 1 - 32 heads (Holstein-Friesian breed) and farm no. 2 - 100 heifers (Simmental breed), in farm № 3 - 800 head of heifers (Simmental breed), in farm №. 100 cows (Simmental breed) and in farms № 5 and № 6 - 230 cows (Holstein-Friesian breed).

All of the base farms were analysed on: economic activity, genealogical analysis of the herd to enter the SmaXtec system into the database, dairy cow productivity, possibility and profitability of using the "Veterinarian Tablet" and "Herd Management" software products.

The main source of information on livestock were data from on-farm record-keeping systems integrated with milking equipment (DairyPlan and AfiFarm) and remote animal health and microclimate monitoring systems (Smaxtec) implemented as part of the project.

Table 2 - Results of implementation of software products "Veterinarian's Tablet" and "Herd Management" on farms in Northern Kazakhstan

| Farm № | Notes |
|---|---|
| 1 | Quite a new farm. It is a small farm where almost all processes are managed by a few people. There is an AfiMilk system installed on the farm, integrated with the milking equipment, which is also used for accounting and cattle management. In the course of the project, the "smaXtec" system was installed on the farm, which demonstrated high efficiency in detecting oviposition, resulting in 100% fertilisation of the breeding herd. In particular periods there was no access to the internet. The developed 'Veterinarian Tablet' programme was demonstrated to the responsible staff. There is no need for an additional product on the farm. |
| 2 | New farm. Previously it did not have any accounting software implemented, it has access to the Internet, for which reason the web-based software package is well suited for bookkeeping.<br>There is a "smaXtec" system installed on the farm (boluses) for remote animal welfare monitoring. At the beginning, the operation of the system was complicated by the lack of a permanent power supply. In order to power the system and the modems, the diesel generator was powered up once or twice a day for half an hour, which resulted in untimely reports of hunting, and as a result the system could not be used to its full potential. In addition, pasture maintenance has led to increased alarms on animal activity as the system is designed to maintain stalls.<br>The mobile application "Veterinarian Tablet" also attracted interest, but in order to use it fully, up-to-date data must be entered into the Herd Management software. |
| 3 | There is a large dairy farm with a milking herd of over 600 head, there is also a large number of Angus beef cattle. Total number of staff on the farm is up to 50 people. The farm has implemented the DairyPlan system, which is fully utilised in the day-to-day running of the farm. In the course of the project, the smaXtec remote monitoring system and FeedNet feed automation system were implemented. FeedNet is in use on a daily basis to plan and manage the preparation of feed mixes and record feed distribution. "Smaxtec is mostly in use as a hunt detection tool, so tracking animal health signals is almost impossible.<br>Staff and farm management were provided with a demonstration of the Herd Management software and training on how to use it. There was little interest in the developed software as the "DairyPlan" system already in use has all the features required for the current operation of the farm. The farm staff understand in advance the complexity of accounting in the two systems.<br>They are more interested in the 'Veterinarian Tablet' mobile app, especially its ability to view farm livestock information offline, right next to the animal, as well as the ability to record veterinary operations right on the spot. Staff understand the advantage of such electronic recording over paper-based recording. In order to ensure the data can be viewed on site, the data has been transferred from DairyPlan to herd management software. Although the farm has access to the internet, the operator's milking parlour, where DairyPlan is installed, is inaccessible to ensure the security and reliability of the system. Thus it makes it difficult or even impossible to continually synchronise data from DairyPlan to Herd Management and vice versa. |
| 4 | There is no in-house technical support with computer hardware and automated accounting systems on the farm. An attempt to introduce Smaxtec, as the most autonomous system among others failed due to a lack of understanding of the need for such a system on the farm. Therefore, there was no reliable electricity supply, Internet access was not paid for, and the mobile application was not used. Other systems (herd management programme) could not be implemented under these conditions in principle. |
| 5 | The farm has a mobile Internet coverage, at the same time it is absent in the automated milking rooms and in the operator's room (metal surfaces screen the signal of the mobile network). The farm uses the “DairyPlan” system to automatically record the milk production of the herd; animals are introduced into the system as they reach their productive age. Integration of “Herd Management” software with “DairyPlan” is not possible under these conditions. At the same time, program "Veterinarian's Tablet" attracted veterinarians of the farm with the ability to view reference information on diseases, objects of veterinary and sanitary purposes and the possibility of preliminary diagnostics of diseases based on the observed symptoms. |
| 6 | The farm is on the lookout for a suitable accounting system, over the years several different systems have changed: "DairyPlan", "DairyComp", "DairyComp305", "Uniform Agri". The possibility of implementing or even just demonstrating additional systems is perceived negatively by employees, as they are exhausted by the changes in the accounting system. At the same time the most stable records are kept in paper journals.<br>The developed 'Herd Management' software and the 'Veterinarian Tablet' mobile application were demonstrated and some suggestions for improvements were received, some of which have been implemented. However for the full implementation of the system it is necessary to update the herd management database, for which the farm currently has no employees. Possibly in the future the data will be transferred from the Uniform Agri system once it has been configured and put into operation.<br>There were also additional suggestions in the "Veterinarian Tablet" programme related to the automation of task control by the farm staff. |

The developed mobile application was installed on the mobile devices of veterinarians of pilot farms, training on working with the application was conducted, recommendations on their further improvement were received, conclusions on the implementation of this software product are reflected in table 2.

**Conclusion:**

The conducted research proves that nowadays it is impossible to obtain quality milk and its derivatives without strict regulation of all technological processes and working cycles by time.

Unreasonable collection and prompt delivery cycles will lead to production and loss of production, the distribution of which will require additional human and financial costs, which will directly affect competition and self-employment.

High quality milk in dairy farming with customer feedback ensures competitiveness in the direction of the dairy industry.

To ensure that modern farm information systems work properly many conditions need to be fulfilled: clear identification of the livestock, availability of equipment, qualified and motivated staff, understanding of the systems used by both management and farm staff, availability of network infrastructure on the farm and access to the internet. In the absence of at least one factor, the economic information system ceases to work. Implementation of the system requires a considerable amount of time and requires a long-term sustained effort in this regard, regulation of internal processes and involvement of responsible persons. If the farm has an accounting system in place, the introduction of an additional system is extremely difficult, as it requires synchronisation of data in two or more systems, which is not feasible. Using even two systems in parallel increases the workload of the personnel responsible for accounting.

Start-up labour costs are high and a lot of livestock data needs to be entered manually. Subsequent accounting is facilitated by the availability of previously entered data, but requires consistency, daily data entry.

Farms commonly do not enter the full number of animals into the accounting systems, but only 4-5 digits, which are mostly displayed on the ear tag or respondent. Such an approach is warranted if only one system is used, but if integration with other systems is required, animal identification conflicts arise, resulting in an inability to communicate between systems. As all systems allow you to track animals by multiple numbers, you must use at least one field in each system to enter a full-size unique local or state animal number, e.g: KZC10987654321, USA636293, AT8738748028.

Another infrastructural problem is Internet access: computers near the milking parlor receiving information from the milking equipment are usually not equipped with Internet access to ensure the security and stability of such equipment (exclude the use of computers for other purposes, exclude the penetration of viruses). Placing computer equipment in a building where milking takes place or where animals are kept increases the risk of failure due to high humidity and proximity to dust / manure / dirt. This should be taken into account when setting up such workplaces, using equipment designed to work in such conditions.

The spectrum of basic problems and needs varies greatly on farms. In order for the economy to be interested in the proposed SW, it must have the functionality to ensure that the most important (at the time of implementation) problematic issues are addressed. Moreover, the software implemented should not significantly increase the workload of farm staff in its implementation; where possible, data should be collected automatically, without human intervention, and made available to responsible staff for analysis as needed.

Overall it can be said that there are people on farms who know how to use modern recording, analysis and management technologies, but for this to become a habit, understanding and guidance from management on how to implement and monitor this process is necessary.

The observations also show that systems handed over as part of a project receive less attention than systems purchased with their own money or on credit.

Undoubtedly, the software developed has shown to be effective in operating and automating processes on dairy farms in Northern Kazakhstan, but for a number of reasons mentioned above, they cannot be used to their full functionality.

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## СҮТ ФЕРМАЛАРЫСЫНДАҒЫ МАЛДАРДЫҢ ӨНІМДІЛІГІН БАҚЫЛАУ ЖҮЙЕЛЕРІ

**Аннотация.** Бұл жобаның өзектілігі мынада: заманауи цифрлық, ақпараттық және зияткерлік технологияларды пайдалану сүт өндірісінің есебін жедел жүргізуге, жануарлар денсаулығының өзгеруіне дер кезінде жауап беруге және табынның көбею процесін тиімді жоспарлауға мүмкіндік береді. Нәтижесінде ресурстық әлеуетті пайдаланудың тиімділігі артады, сонымен қатар инвесторлар үшін сүтті мал шаруашылығының кірістілігі мен тартымдылығы артады. Өзірленген жүйелер ауылшаруашылық тауар өндірушілеріне деректерді автоматтандырылған талдау негізінде нақты шешімдер қабылдауға мүмкіндік береді. Сүтті мал шаруашылығында шаруашылықтарды тұтынушының сұранысына қайтарып алумен бірге сүттің жоғары сапасы мал шаруашылығы саласының бағыты бойынша бәсекеге қабілеттілікті қамтамасыз етеді. Мақалада ал шаруашылығындағы сүт өнімдері өндіруді бақылауды автоматтандырудың математикалық моделі егжей-тегжейлі сипатталған, бұл өнім нарығын теңестіруге әкеледі. Сондай-ақ, Солтүстік Қазақстанның сүт фермаларындағы жануарлардың жай-күйін есепке алу үшін қазірдің өзінде жасалған бағдарламалық өнімдерді енгізу нәтижелері сипатталған. Жасалған бағдарламалық жасақтаманы пайдалану бойынша бірнеше ұсыныстар берілген. Шаруашылықтартың әрқайсысының нәтижесі, сипаттамалары мен жағдайы бүгінгі күнге дейін егжей-тегжейлі сипатталған. Қорытындыларды жергілікті фермерлер өндірістік процестерді ұйымдастыру үшін ескереді және қарастырады. Бұл міндетті жүзеге асыру С. Сейфуллин атындағы Қазақ агротехникалық университетінің базасында жүзеге асырылуда. Ауылшаруашылық өндірісіндегі көптеген процестерге арналған ақпараттық технологиялардың шешімдерін әзірлеу және енгізу бойынша ғылыми топ құрылды. Бұл ғылыми бағдарлама - Солтүстік Қазақстанның сүт шаруашылықтарында сандық технологияларды қолданудың озық тәжірибесін енгізуге және бейімдеуге бағытталған алғашқы кешенді шешім.

**Түйін сөздер:** сараптамалық жүйесі, деректерді талдау, бақылау, сүттілік мөлшері, жасанды сана, сандық технологиялар, бірлесу, диагноз.

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## СИСТЕМЫ КОНТРОЛЯ ПРОДУКТИВНОСТИ МОЛОЧНЫХ ЖИВОТНЫХ

**Аннотация.** Актуальность данного проекта состоит в том, что использование современных цифровых, информационных и интеллектуальных технологий позволит оперативно вести учет молочной продуктивности, своевременно реагировать на изменения здоровья животных, эффективно планировать процесс воспроизводства стада. В результате повысится эффективность использования ресурсного потенциала, а также доходность и привлекательность молочного скотоводства для инвесторов. Разработанные системы позволят сельскохозяйственным товаропроизводителям принимать конкретные решения на основе автоматизированного анализа данных. В молочном скотоводстве высокое качество молока в совокупности с отзывом хозяйств на запрос потребителя обеспечивают конкурентную способность по направлению скотоводческой отрасли. В статье подробно описана математическая модель по автоматизации контроля производства молочной продукции на фермах, что повлечет за собой выравнивание рынка продукции. Так же описаны результаты внедрения уже разработанных программных продуктов по учету состояния животных в молочных фермах Северного Казахстана. Приведены некоторые рекомендации по использованию разработанных программных обеспечений. Подробно были описаны результате по каждой из ферм, характеристика и состояние ферм на сегодняшний день. Полученные выводы будут учтены и рассмотрены фермерами местного уровня для организации процессов на производстве. Реализация данной задачи проходит на базе Казахского агротехнического университета им. С. Сейфуллина, создана научная группа по разработке и внедрению ИТ решений для многочисленных процессов в сельскохозяйственном производстве. Данная научная программа является первым комплексным решением, которая направлена на внедрение и адаптацию передовой практики в сфере применения цифровых технологий в молочных хозяйствах Северного Казахстана.

**Ключевые слова:** экспертная система, анализ данных, мониторинг, объем удоя, искусственный интеллект, цифровые технологии, интеграция, диагноз.

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