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DIGITAL TRANSFORMATION IN BEEF CATTLE BREEDING: THE EXPERIENCE OF CREATING A SMART FARM "PETAL"

ЕТТІ МАЛ ШАРУАШЫЛЫҒЫНДАҒЫ ЦИФРЛЫҚ ТРАНСФОРМАЦИЯ: СМАРТТАРДЫ ҚҰРУ ТӘЖІРИБЕСІ-ФЕРМАЛАР "PETAL»

ЦИФРОВАЯ ТРАНСФОРМАЦИЯ В МЯСНОМ СКОТОВОДСТВЕ: ОПЫТ СОЗДАНИЯ СМАРТ-ФЕРМЫ «PETAL»

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Abstract. The relevance of the topic is determined by the significance of digital technologies in beef cattle breeding, which allow increasing the profitability of the agro-industrial complex through cost optimization and more efficient allocation of funds. The competitiveness of enterprises of the agrarian sector directly depends on the use of the results of innovation activity, which allows to increase the value by increasing labor productivity. The article presents different points of view of researchers on the problems in the agrarian sector of the Republic of Kazakhstan. One of them - intensification of labor process is recommended to solve by modernization of agricultural production and application of high-tech smart system "RETAL". The *aim* is to determine the financial feasibility of its implementation, which is based on the complexes of "smart" pasture technologies. Research *methods* are based on the system analysis of works of domestic and foreign scientists, familiarization with analytical reviews of research institutes and centers, materials of scientific and practical conferences on the studied issues, data of expert survey of farm workers. *Results* - a unified approach combining goals and objectives of livestock and pasture management was analyzed. *Conclusions* - in conclusion, the authors note that the use of electric

fencing minimizes the labor of workers, reduces wage costs, as well as costs associated with the duties of shepherds, significantly simplifies the implementation of preventive measures for the maintenance of livestock on grazing lands. Of practical importance is the use of a methodology for calculating the value equivalent of benefits and their comparison. The advantage of smart-farm is a complex solution combining the principles of cattle herd regulation and grazing on pasture lands in a single technological cycle. This is a new concept to increase the volume and improve the quality of production and is an ideal environment for robotics.

Аңдатпа. Тақырыптың өзектілігі шығындарды оңтайландыру және қаражатты неғұрлым тиімді бөлу есебінен агроөнеркәсіптік кешеннің рентабельділігін арттыруға мүмкіндік беретін етті мал шаруашылығындағы цифрлық технологиялардың маңыздылығымен айқындалады. Аграрлық сектор кәсіпорындарының бәсекеге қабілеттілігі еңбек өнімділігінің өсуі есебінен құнды ұлғайтуға мүмкіндік беретін инновациялық қызмет нәтижелерін пайдалануға тікелей байланысты. Мақалада Қазақстан Республикасының аграрлық саласындағы проблемаларға зерттеушілердің әртүрлі көзқарастары ұсынылған. Олардың бірі - еңбек процесін қарқындату ауыл шаруашылығы өндірісін жаңғырту және «Petal» жоғары технологиялық смарт жүйесін қолдану арқылы шешу ұсынылады. *Мақсаты* - негізінде «ақылды» жайылымдық технологиялар кешені жатқан оны енгізудің қаржылық орындылығын анықтау. Зерттеу *әдістері* отандық және шетелдік ғалымдардың еңбектерін жүйелі талдауға, ҒЗИ мен орталықтардың талдамалық шолуларымен, зерттелетін мәселелер бойынша ғылыми-практикалық конференциялардың материалдарымен, шаруашылық қызметкерлерінің сараптамалық сауалнамасының деректерімен танысуға негізделеді. *Нәтижелер* - мал басы мен жайылымдарды басқарудың мақсаттары мен міндеттерін біріктіретін бірыңғай тәсіл талданды. *Қорытынды* - электрлік қоршауды қолдану жұмысшылардың еңбегін барынша азайтады, жалақы шығындарын, сондай-ақ малшылардың міндеттеріне байланысты шығындарды қысқартады, жайылымдық жерлерде малды күтіп-бағу бойынша алдын алу іс-шараларын жүргізуді едәуір жеңілдетеді. Пайданың құндық баламасын есептеу әдістемесін пайдалану және оларды салыстыру практикалық мәнге ие. Смарт ферманың артықшылығы ірі қара мал табыны мен жайылымдық жерлердегі жайылымды бірыңғай технологиялық циклде реттеу қағидаттарын үйлестіретін кешенді шешім болып табылады. Бұл - өнім көлемін арттыруға және сапасын жақсартуға мүмкіндік беретін жаңа тұжырымдама, робототехника үшін тамаша орта болып табылады.

Аннотация. Актуальность темы определяется значимостью цифровых технологий в мясном скотоводстве, позволяющих повысить рентабельность агропромышленного комплекса за счет оптимизации затрат и более эффективного распределения средств. Конкурентоспособность предприятий аграрного сектора напрямую зависит от использования результатов инновационной деятельности, позволяющих увеличить стоимость за счет роста производительности труда. В статье представлены различные точки зрения исследователей на проблемы в аграрной отрасли Республики Казахстан. Одну из них – интенсификация трудового процесса рекомендуется решить путем модернизации сельскохозяйственного производства и применения высокотехнологической смарт системы «Petal". *Цель* - определение финансовой целесообразности ее внедрения, в основе которой лежат комплексы "умных" пастбищ--ных технологий. *Методы* исследования основываются на системном анализе трудов отечественных и зарубежных ученых, ознакомлении с аналитическими обзорами НИИ и центров, материалами научно-практических конференций по изучаемым вопросам, данными экспертного опроса работников хозяйства. *Результаты* – проанализирован единый подход, комбинирующий цели и задачи управления поголовьем и пастбищами. *Выводы* – в заключении авторы отмечают, что применение электрического ограждения минимизирует труд рабочих, сокращает расходы на заработную плату, а также затраты, связанные с обязанностями пастухов, существенно упрощает проведение профилактических мероприятий по содержанию скота на пастбищных угодьях. Практическое значение имеет использование методики расчета стоимостного эквивалента выгод и их сопоставление. Преимуществом смарт фермы является комплексное решение, сочетающее принципы регулирования стада крупного рогатого скота и выпаса на пастбищных землях в едином технологическом цикле. Это – новая концепция, позволяющая повысить объемы и улучшить качество продукции, является идеальной средой для робототехники.

Key words: agriculture, beef cattle breeding, smart technologies, labor productivity, profitability of production, return on investment, efficiency of funds allocation.

Түйінді сөздер: ауыл шаруашылығы, етті бағыттағы мал шаруашылығы, смарт технологиялар, еңбек өнімділігі, өндірістің рентабельділігі, инвестицияның қайтарымы, қаражатты бөлудің тиімділігі.

Ключевые слова: сельское хозяйство, мясное скотоводство, смарт технологии, производительность труда, рентабельность производства, окупаемость инвестиций, эффективность распределения средств.

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Introduction

Kazakhstan has a great potential for agriculture development – it has sufficient water resources, a relatively clean production base and the proximity to world markets. This presents opportunities for production and sale of high-quality agriculture products (Lun V.) [1]. Increasing labor productivity and ensuring competitiveness of agriculture, and particularly farming, calls for digital transformation based on the latest innovations in information technology.

The effective functioning of agricultural enterprises, farms and meatoriented households is the basis for the sustainable development of meat sub-complex of the region (Tarshilova L.S., Ibyzhanov A.J., Kazambayeva A.M.) [2].

A great share of livestock is raised on small farms, which hinders adoption of modern technologies. Most small private farms cannot install adequate technological equipment, which adversely affects product quality.

A full-scale state-wide control of all farms is hardly possible. This leads to the appearance of small-scale commodity; livestock breeding is particularly affected. Meanwhile, there is also the issue with animal reproduction. Consequently, prevalence of outbred cattle makes it impossible to count on quality products and maintenance of a competitive position on the market.

Digitalization has transformed every sector – and agriculture business is no exception (UC Davis In Focus…) [3]. However, at present, the share of farmers in Kazakhstan using digital technologies is insignificant. This has a negative effect on the national development of the industry and reduces margins of agribusiness.

Digital technologies enable to lower production costs, improve production quality and energy efficiency in production. The adoption rate of digital technologies in farming remains low, although Kazakhstan is one of the leaders among the CIS countries in terms of the pace of digitalization, according to Geomir (Russian digital solutions…) [4].

The importance of accelerating agribusiness digitalization arises from the need to boost agricultural production efficiency and substantially reduce the number of workers needed to produce target volumes of agricultural products. One promising area is precision livestock farming. Smart farming can increase cattle productivity and product quality.

Thus, the purpose of the study is to determine the economic efficiency of the implementtation of the “Petal” system, which is based on complexes of "smart" pasture technologies.

In this regard, it is necessary to solve the following tasks: calculate the cost of components of this system, as well as the cost of organizing animal watering and calculate the economic effect of using this system in comparison with traditional grazing technology.

During the study period, at least 60 animals were kept in the experimental pasture.

Literature Review

Sereda N.A. [5] observed that, for an extended period, information technologies in agriculture were predominantly utilized for the automation of accounting processes.

In recent times, however, digital transformation in livestock farming has manifested in a number of different ways: cattle monitoring; automatic and robotic feeding and care for the livestock; animal identification; production and operations management.

In another publication, Mirzojanc Ju.A., Sereda N.A. [6] defined economic efficiency in the context of new equipment and technology adoption as the correlation between cost and results achieved, emphasizing the cost of production. In the contemporary era, the overarching objective, as postulated by Borrero J.D., Mariscal K.A. [7], is the industrialization and digitalization of the agricultural sector, the establishment of a tripartite alliance between the state, science, and business, and the formulation of a comprehensive support system for agricultural producers.

As demonstrated by Strekozov N.I., Moshkutelo I.I., Sivkin N.V et al. [8], the implementation of innovative solutions in pig, beef, and dairy cattle farming has facilitated the enhancement of animal reproduction and productivity, particularly in the context of adapting imported animals to local conditions Zhumaxanova K.M., Yessymkhanova Z.K., Yessenzhigitova R.G et al. [9] identified low productivity and high costs as the primary challenges facing the agribusiness sector in Kazakhstan. The authors posit that digital transformation will (1) facilitate a reduction in production costs and risks associated with climate change, (2) enhance livestock productivity, (3) boost labor productivity, and (4) deter crop and livestock theft.

A case study of using new equipment in beef cattle farming in Kostanay and West-Kazakhstan regions by Nasambaev E.G., Gizzatova A.I., Ahmetalieva A.B. [10] showed labor productivity growth and reduction in unit production costs. According to the authors' data, these factors pay back capital investment and growing current costs of production.

Some articles reflected the issue of adoption of innovations in farming. Emphasizing the efficiency of digital transformation, Guntoro B., Hoang Q.N., A'yun A.Q. et al. [11] discussed the need to establish a legal and institutional framework as the basis for the national spatial data infrastructure Fedorov A.D., Kondrat'eva O.V., Slin'ko O.V. [12] asserted that, although a prevalent trend over the past decade, the integration of digital technologies in agricultural practices had not yet achieved widespread adoption.

Specifically, the authors posited that accelerating the adoption process would enhance the efficiency of agricultural production and reduce labor costs for certain operations. Horn J., Isselstein J. [13] identified two key challenges to the implementation of smart farming: low user awareness and a lack of financial resources for farmers to acquire and operate digital solutions. Additionally, the author highlighted the need for state-sponsored initiatives to support the acquisition of these technologies. To address these issues, the author proposed the development of information and counseling services in agribusiness, including the provision of shared access to smart farming technologies for farmers

However, the existing literature on the topic to date doesn't include any research looking into the economic efficiency of smart farming technologies use in horse breeding and beef cattle farming, which confirms the relevance of this study.

Materials and methods

The methodology employed in this study is founded upon a comprehensive and systematic examination of the scholarly works of both domestic and international scientists and the use of analytical reviews of research institutes and centers, materials of scientific conference and seminar on the topic of the study, reports of the research staff about the system implementation and data gathered by a survey of farm employees.

A comparative cost-benefit analysis method was used to evaluate the "Petal" system, comparing between two scenarios: before and after its implementation, that is, with a traditional grazing system and after the introduction of the "Petal" system.

The economic impacts were considered to be the savings from reducing resource consumption (in monetary terms) which determine the system cost and the amount equivalent to the cost reduction.

In the course of the research, economic and statistical methods were used: analysis and synthesis, deduction and induction, the method of comparative cost-benefit analysis.

Results

The "Petal" system (henceforth referred to as "the System") developed by the S. Seifullin Kazakh Agro Technical Research University (KATRU) was deployed on premises of the North Kazakhstan Agricultural Research Station (NKARS).

It should be noted that the research station's rigorous accounting standards and comprehensive data management practices ensured the availability of complete and detailed information related to the research project, including data on system efficiency.

The system is based on a variety of intelligent farming technologies, including integrated systems for remotely monitoring various parameters and animal behavior on pastures. These systems include:

- electric fencing;
- a stress-free livestock weighing system connected to a water or feed dispenser;
- an automated animal identification and feed control platform;
- an automated veterinary treatment platform.

These systems allow animals to be kept in barns during the winter and to graze freely on native or improved pastures, either fenced with barbed wire or electrified fences, without human supervision.

An area of 70 hectares was selected from the total area of the NKARS pastures by cluster fencing 7 paddocks of on average 19 hectares each, designed in a shape of petals with a shared access to the watering hole. During the duration of the study, the experimental field was home to at least sixty animals.

The financial outlay required for the procurement of the requisite equipment for the "Petal" system is set out below. This figure has been arrived at by taking into account the components already installed on the experimental pasture equipment at the NKARS farm, are listed in table 1.

Table 1 – Component costs for the “Petal” System

Title	Unit	Amount	Price, thousands tenge/unit	Total, thousands tenge
Generator OLLI 250	pcs	2	90.9	181.9
Stranded wire 3 mm/1, 000 m	bundle	22	28.4	624.9
Plate clamps 3 mm	pcs.	50	20.0	10.0
Reinforced ring insulator	pcs	2.5	19.5	487.3
Spring set for the gate	set	8	34.87	27.9
Lighting arrester	pcs	2	5.87	11.7
Ground cable	pcs	4	5.38	21.5
High-voltage cable	m	100	4.67	46.7
Fittings A3 10 A400C/A500C (1.95 m)	pcs	1.2	628.8	754.6
Solar generator to power the electric fence	pcs	1	160.0	160.0
Drinker system	pcs	2	250.0	500.0
Scales	pcs	4	1 088.0	4 352.0
Spraying equipment	pcs	1	40.0	40.0
Solar power plant for other system elements (apart from the fence)	pcs	1	1 774.0	1 774.0
Grand total				8 992.5
Note: calculated by the authors on the basis of data from farms				

Additionally, there were costs for livestock watering on the experimental pasture (table 2). It is believed that animals that consume green feed, which can contain up to 75 to 90% (percent) water, require less water than when they consume other types of food. However, the water in plants is more difficult for animals to digest compared to pure water or water mixed with the feed. The amount of water in plants cannot fully satisfy the water needs of livestock. Therefore, in practice, after consuming green feed, animals still require access to pure water, even in larger quantities than what would be expected based on the water content of the green feed.

Table 2 – Livestock watering costs

Name	Unit	Amount	Price, tenge/ unit	Total, tenge
Borewell drilling costs	m	100 m	50 000	5 000 000
Bore-hole pump	pc	1	300 000	300 000
Water analysis	service	1	50 000	50 000
Bore water use cost (108 m^3)	1 000 m^3	145.73	15. 74	15.74
Grand total				5 350 015.7
Note: calculated by the authors on the basis of data from farms				

The sources of potable water for livestock grazing on the experimental pasture included (i) a trench situated 200 metres away from the pasture, (ii) and a borehole with a depth of 35 metres located 100 metres from the pasture site. The monthly water requirement for each animal was calculated based on the recommended volume for an open grazing system, amounting to 60 litres per day. The water was delivered from the borehole directly to the drinking point, with the distance from the drinking point to the most distant point on the experimenttal pasture reaching up to 1(one) kilometre.

The total cost of the equipment utilized in the experimental pasture was 14 342. 5 thousand tenge.

In addition to these costs, video surveillance was provided using the NKARS equipment – therefore, the NKARS did not include these costs into the total equipment cost for the “Petal” system.

The economic efficiency of the “Petal” system. The data was collected from May 2022 to October 2023. In terms of the economic efficiency, during the research process several factors were identified and, based on the NKARS data, the impact size was measured (table 3).

The main sources of the observed economic impact of an ongoing nature (excluding investments) were: (i) wage cost reduction, (ii) increased weigh gain through better pasture conditions and also (iii) conditional income from increased crop yield.

The introduction of electric fencing in the grazing area has led to a substantial decrease in the labor needs for shepherds, resulting in a notable decrease in associated labor expenses. The role of shepherds has changed. Instead of performing physically demanding and repetitive tasks that required physical strength and energy to manage the herd, their duties now involve monitoring the equipment and moving cattle between designated areas within the pasture.

To illustrate, the investigation uncovered that manual labor was exclusively utilized for the following objectives: moving the fence; adjusting the grazing path;

shifting the cattle to the new pasture; providing water for the cattle and replenishing the water in the troughs.

In total, these tasks necessitated up to two hours of work, compared to the continuous presence on the pasture when employing the conventional method, resulting in a four-fold decrease in labor expenses per eight-hour workday.

Table 3 - Comparative analysis of the effect indicators from the application of the “Petal” system

Metric	Technology		Difference, + / -
	traditional	“Petal”	
The number of shepherds, people	4	2	- 2
Working hours, person/ hours per month	1 080	540	-540
Payroll costs of employees with deduction, thousands tenge per month	944.6	472.3	-472.3
Average monthly wage of one herdsman with reductions, thousands tenge	236.15	236.15	-
Horses (plow cattle) for grazing, number	6	-	-6
Horse cost, thousands tenge	3 202.8	-	-3 202.8
-Price per horse, thousands tenge	516.6	516.6	-
- Horse feeding costs, thousands tenge	51.6	-	- 51.6
Crop yield conditional income, tenge per 70 ha	330 400.0	826 000.0	+495 600.0
Crop yield, t/ ha	0,3 – 0,5	0,9 – 1.1	+0.6
Average fodder price, tenge / ton	11 800.0	11 800.0	-
Conditional income from 1 ha, tenge	4 720.0	11 800.0	+7 080.0
Livestock weight gain income (60 head of cattle) per month, thousands tenge	2 073.6	2 448.0	+374.4
Daily average weight gain, gram	720	850	+130 (+18,1 %)
Average price for cattle sale, tenge/ kg (in live weight)	1 600.0	1 600.0	-
Income from monthly weight gain per head of cattle (30 days), thousands tenge	34.56	40.8	+ 6.24
Total cost [3] + [5], tenge	4 147.4	472.3	+3 675.1
Total income [6] + [7], tenge	2 404.0	3 274.0	+870.0
Effect			+4 545.1
Incl. monthly current expenses, tenge	-	-	+929.3
Note: calculated by the authors on the basis of data from farms			

Moreover, the use of the “Petal” system substantially simplified taking preventive action on pastures. In particular, in traditional grazing 10 additional support workers were required to weigh animals and carry out veterinary activities. For 60 head of cattle, all these activities consumed nearly 24 hours. Furthermore, the animals experienced stress due to human interaction, which adversely affected their appetite and resulted in weight loss.

In addition to labor costs, using the cost of labor, the NKARS farm, which relied on traditional grazing methods, required up to four shepherds for 60 head of cattle. This meant they needed to maintain a herd of six horses, with two as backup. Each horse received a daily ration consisting of (i) up to 6 kilograms of oats (13.8 thousand tenge per ton), (ii) up to 6 kilograms of straw (6.0 thousand tenge per ton), and (iii) up to 12 kilograms of hay fodder (14.0 thousand tenge per ton), which amounted to approximately 8 600 tenge per month. Therefore, the cost savings for maintaining six horses amounted to 51 600 tenge.

The implementation of solar-powered generators resulted in a 26.3% decrease in operational expenses for electricity consumption (table 4).

Table 4 – Monthly cost of electricity for the experimental pasture

Metric	Technology		Difference, + / -
	traditional	“Petal”	
Monthly cost of electricity, tenge	45, 3	33, 4	-11, 9
Note: calculated by the authors on the basis of data from farms			

For example, at the prevailing rate of (17.86 tenge per kilowatt-hour), electricity consumption by the borehole pump, with a capacity of 2 kilowatts per hour, used for five hours a day, would incur costs in the amount of 5 358 tenge per month.

Discussions

It is noteworthy that during the course of their research, the scientists established a link not only to a stationary electrical ground power supply, but also to solar energy. Initially, this was seen as a contingency plan to maintain the experiment in the event that the solar generator malfunctioned, ensuring the smooth operation of the system despite adverse weather conditions or any other unforeseen circumstances.

A potential consequence of a lack of electricity supply to the fence could be that animals might breach the barrier and escape from the enclosed pasture, potentially resulting in a loss of control over livestock (Orazbaeva A.S., Tokenova S.M., Mogilnyy S.V.) [14].

Moreover, one of the key advantages of the "Petal" system is its cost-effectiveness compared to alternative solutions, particularly imported ones. The installation process is relatively straightforward, which helped reduce the overall project expenses. For example, the fencing posts can be constructed using readily available materials, thereby saving up to 750,0 thousand tenge. Additionally, a car battery can be used instead of a solar panel, along with the installation of a metal grid and wiring (Tokenova S., Orazbayeva A., Ismailova A.) [15].

Consequently, in light of the current market conditions, the historical cost structure, technological innovations, and manufacturing processes, as well as the alterations to the technology resulting from the implementation of the NKARS system, which primarily aim to reduce costs and enhance positive effects, it can be anticipated that the payback period for these expenses will occur within six months after the completion of preliminary activities and the initiation of operation of the "Petal" system.

The system has significantly expanded the capabilities of livestock control by increasing access to relevant data.

Conclusion

1. *Biological effectiveness.* The "Petal" system facilitated the smooth implementation of preventive measures in a stress-free manner. Animals, acting voluntarily, were guided to a water source where their weight was carefully measured. At the same time, they received treatment using specialized equipment that was seamlessly integrated with the drinking troughs. This innovative approach significantly reduced the risk of injury and the associated stress-induced weight loss, ensuring that the animals were not subjected to the stress associated with human interaction or equipment use.

In addition to the stress-free weighing and veterinary activities, there is a biological impact from the use of the "Petal" system achieved by the development of a reflex in cattle to concentrate on feeding while being inside the fenced area. The reflex is developed by an electrical shock that the animal receives when contacting the electric fence. The zap of shock is powerful enough to be felt but does not harm the animals. Moreover, the system helps to develop maternal instinct in cows as it becomes possible to raise calves without the aid of workers.

2. *Ecological effectiveness.* The ecological impact is achieved by the optimization of grazing pressure through rotational grazing and by the increase of their yielding capacity, which minimizes the risk of land degradation. Pasture revegetation becomes easier to control for farm workers, while cattle get access to abundant feed after moving to a new area.

3. *Employee attitudes towards the "Petal" system adoption.* The analysis of interviews carried out with the North Kazakhstan Agricultural Research Station workers about the impact of the "Petal" system adoption, demonstrated (similarly to that expressed by workers of other farms where other systems were used) a prevailing view that the long-term economical impact from the System will grow due to the synergistic effect of biological (increased livestock productivity) and ecological (increased crop yield) impacts.

4. The employees highlighted the significant time and manual labor savings achieved through the automation of cattle processes as the primary advantages of the System. Middle-level managers also endorsed the notion that the implementation of the System substantially enhanced the potential for cattle management

by providing enhanced access to pertinent data.

As one respondent noted, the data generated by the System, allows, on the one hand, greater adaptability in managerial decisions based on production conditions, and on the other hand, improved sustainability in production through the ability to adjust to changing circumstances.

5. The System's key strength lies in its holistic approach, which addresses both cattle and pasture management issues in a single technological framework. However, it was noted that the increased scope and quantity of data necessitates the development of new workplace competencies for personnel engaged in reporting and administration, particularly those related to handling extensive data sets.

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