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The Quality Function in Determining the Effectiveness of Example Bioeconomics Tasks

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Abstract. The aim of the publication is to develop theoretical and methodological foundations and practical recommendations for determining the efficiency of biotechnological processes with the subsequent justification of technical parameters to ensure a high level of viability of bio-objects. In the course of the conducted scientific research, the criteria of quality function were defined and formalised, in accordance with which the conditions of biotechnological processes of laser division of embryo were formulated as a single case in the realisation of the economic mechanism of biotechnology. This makes it possible to ensure a high level of cattle (cattle) productivity, reduce the time for the reproduction of livestock and reduce the costs of movement, trade and transportation of cattle. The quality function of the biotechnological process of laser division of embryo is formulated on the basis of criterion of non-exceeding of the temperature field in cells of blastomeres and the predetermined acceptable value that allowed one to take into account the main parameters and to propose the criterion of biotechnological process optimisation. As a promising task for the development of the bioeconomy as an economic mechanism in implementing biotechnologies, the necessity of determining the quality function by formalising the integral indicator of efficiency has been established, This enables one to ensure a high level of commercialisation of biotechnologies, to increase the productivity of agricultural animals, and to suggest alternative methods for the quick renewal of livestock.
Key words: bioeconomics, biotechnology, functional value, cattle, embryos, uniqueness criterion.

Introduction

The problem of providing the population with high-quality livestock products is not only one of the central problems in agriculture, but also interrelated with a number of other scientific problems, in particular the theoretical and methodological and practical foundations of the development of bioeconomics, namely the construction of the organisational and economic mechanism of biotechnology processes in practice and increasing their effectiveness regardless of the sphere of application. The effective solution of this problem in animal husbandry needs, in turn, to work out effective directions of optimisation of parameters of bio-objects and technical means for automation of the biotechnological process. Further justification of technical parameters to ensure a high level of viability of the bio-object will allow one to obtain a high level of productivity of farm animals, reduce costs and reduce the time of reproduction of livestock. The study of biotechnological process of laser fission of elite animal embryos under the observance of restrictions on the temperature field in the embryo and the parameters of the mobile radiation source will not exceed the thermal stability and ensure the viability of the obtained parts of the bio-object (embryo).

Consequently, the solution to the problem of providing the population with food resources is possible through the practical use of biotechnology, representing a set of methods and ways of obtaining biological products with the application of innovative technological, selection and genetic, microbiological solutions. In this regard, determining the effectiveness of biotechnological processes through technical parameters to ensure a high level of viability of biological objects and high productivity of farm animals in livestock complexes is of particular relevance.

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Given the complex nature, the long evolutionary path of development, the issues regarding the formation of the organisational and economic mechanism in the implementation of biotechnology and bioeconomics as a science that studies the transformational processes within it, the basis for our study is the results of scientists in various scientific fields.

The lack of a single definition of the term "bioeconomics" and the diversity of opportunities to use bio-objects as a subject of theoretical and practical research at the present stage of development of science and technology does not allow one to identify a single approach to determining the effectiveness of the biotechnological process and requires additional research.

It should be noted that the problems of formation and management of the organisational and economic mechanism of agricultural enterprises have been studied in the works of Shubravskaya (2010), Levkina (2013; 2014), Abuselidze et al., (2021), Butenko (2018), Penev & Andreev (2020).

The theoretical basis for modelling the influence of an electromagnetic radiation source, including a laser, on a bio-object was provided by fundamental works of many scientists, who in those years mainly investigated technical parameters and characteristics, including Stoyan and Putyatin (1982).

Taking into account the relevance of biotechnological research for solving the food problem, the aim of the publication is to develop theoretical and methodological foundations and practical recommendations for determining the efficiency of biotechnological processes with subsequent justification of technical parameters to ensure a high level of viability of the bio-object. This will make it possible to obtain a high level of productivity, reduce costs and reduce the time for the reproduction of livestock of farm animals.

The scientific novelty of the presented research lies in the improvement of the methodological approach to determining the performance indicators of biotechnological processes through the introduction of a single integral performance indicator, a formalised version of which is the quality function proposed by us, based on applied mathematical models and numerous methods of their implementation, which together create a computing structure, allowing one to identify certain regularities, and predict the temperature regimes. This will improve the efficiency (speed and accuracy) of the implementation of applied optimisation problems in bioeconomics.

Materials and Methods

The theoretical and methodological basis of the research are the fundamental provisions of economic theory and mathematical analysis, achievements of domestic and foreign economics and biophysics on the impact of external factors of laser radiation on the bio-object. When solving the problems the following methods were used: abstract-logical (when forming a structural-logical research scheme, determining indicators of biotechnological process efficiency, to generalise the features of the laser beam effect on the bio-object and its viability), monographic (when forming a system of data on the results of biotechnological research), economic-mathematical (for the formalisation of mathematical models and analysis of peculiarities of the optimisation process of the laser beam effect on the bio-object under sterile conditions to provide a high level of biotechnology efficiency), synthesis methods (to determine basic parameters of the biotechnology process taking into account specifics of bio-object), statistical methods (for expert evaluation of limiting values of control parameters of laser action on the multilayer microbiological object in order to find rational values.

In the 21st century, biotechnology serves as a real tool for solving numerous problems of mankind, among which are food supply, as well as the creation of effective medical drugs for incurable and infectious diseases. Acting as one of the convergent NBIC-technologies, biotechnology forms bioeconomics and bio-society. The synergistic combination of branches of science developing in close interconnection and interdependence, such as nanotechnology, biotechnology, biomedicine, information technology, cognitive science, forming a new technological mode, allow the rapid development of scientific and technological progress and solve problems that previously seemed unresolved (Chekman & Nebesnaia, 2011).

As a rule, bioeconomics is considered as an economic mechanism for the implementation of biotechnology (Corning et al., 2018). This does not mean that bioeconomics is a completely new branch of the economy, it acts as a basis for the mechanism of sustainable development of the world economy, allowing one to avoid cyclicality in production and marketing activities. Many works are devoted to the issues of cyclicality of the world economy and the need for transition to a sustainable state; among such works are those of N. F. Kondratiev (2002), Tsypkin & Pakulin (2011), Voronkova (2019), Shkodina & Yurkov (2011), Ohanisian *et al*., (2022) and other scientists whose research results remain relevant. The transition to a new stage of development of the NTP, namely digital and information technology, actualises the topic of research and determines its timeliness. Characteristic features of this stage are the integration of digital and information technology in all spheres

of life and human activities. They influence the high rate of innovation, social processes in society, as lifestyles, activities, means of communication are changing (Schwab, 2016). The new technological mode causes the transformation of the social world order, requiring the development and widespread use of nanotechnology, biotechnology, information and cognitive technology. The optimal ratio of major and minor industries not only affects the further development of the world economy as a whole, but also supports its development or self-development at a certain level (Corning *et al*., 2018).

Results and Discussion

Some people identify the concepts of "bioeconomics" and "green economy," drawing attention to the association of biological objects with the colour green. However, international organisations under the "green economy" consider a sustainable economy that provides a better quality of life for people as part of the realisation of the environmental potential of planet Earth (UNEP, 2009) or an economy aimed at social development, when economic growth occurs simultaneously with the environmental responsibility of mankind for their actions (International Chamber of Commerce, 2011). The best-known definition is that it is an economy that aims to simultaneously achieve economic and environmental goals (Rio+20 Objectives and Themes of the Conference (UNCSD, 2011)).

The diversity of the concept of "bioeconomics" actually boils down to one thing: it is an economy based on the systematic use of biotechnology or an economy based on the processes of transforming renewable biological resources into bioenergy, food or feed products with high added value (European Forum for Industrial Biotechnology, 2015). Since bioeconomics explores renewable and non-renewable biological resources, which is now relevant given the trends in the development of certain types of scientific knowledge, we believe that the essence of this definition most corresponds to the following. Bioeconomics should be understood as the science that provides for the use of biotechnology to develop new technological processes and new products, renewable and non-renewable biological resources, efficient bioprocesses in order to ensure sustainable production and integration of biotechnology in various fields of activity, measures of biodiversity loss and to create a new economic environment (Organization for Economic Cooperation and Development, 2009; Srinivasu and Zawka, 2020). As stated in (Corning *et al*., 2018), bioeconomics must be based on the observance of the principles of sustainable harmonious development of the system "economy - society – bio-sphere", and be based on the principles of complexity and synergy. We agree with the conceptual approach to bioeconomics as an innovative tool for addressing a number of problems of a global character: economic, social, food, medical, ecological and so on (Kochetkov & Honcharenko, 2020). It is the interdisciplinarity of bioeconomics that allows us to solve problems in an integrated manner and achieve a synergistic result (Vdovichen & Vdovichena, 2018).

Bioeconomics offers ways to effectively use natural resources to meet the needs of the population of the world and solve the problem of food security. L.P. Zhiganov points out that the means of production in bioeconomics are living organisms, which are used by employees of biotechnology companies in specific conditions (Zhyhanova, 2018). So, the basis of the science of "bioeconomics" is the systematic use of biotechnology, representing: "bios" - life, "techno" - art or skill, "logos" - word, training, science (Vdovichena, 2017).

Currently, Ukraine remains a passive participant in the world transfer of biotechnological solutions or takes part as an importer of developments in the field of breeding and genetics, including seeds of high-yielding varieties, hybrids of food plants and young high-yielding animals (Rudenko *et al*., 2017; Levkina, 2013). This is due to a number of factors, among which, of course, are factors of a legal, economic, financial and social nature. In addition, integration ties between scientific institutions and business enterprises are important; the implementation of mechanisms to attract investment in the sphere of scientific research and the development of appropriate infrastructure is effective (Kochetkov & Honcharenko, 2020).

Biotechnology as a branch of the world economy is developing at a super-high rate. According to estimates of leading international organisations, in 2030 up to 3% of GDP of highly developed countries of the world will be provided by biotechnology. For developing countries, the figure is expected to be much higher and will reach 10%. Biotechnology will provide about 80% of the production of medical drugs, which in the context of the COVID-19 pandemic is extremely relevant in terms of creating drugs for the prevention and treatment of the virus. Up to 35% of chemicals, 30% of energy resources and 50% of agricultural production will be produced using modern biotechnology solutions. Overall, the global market for biotechnology in 2025 will exceed $2 trillion (Arundel & Sawaya, 2009; Kyzym *et al*., 2021).

The leaders in the development and use of biotechnology are undoubtedly highly developed countries of the world. Innovation requires large investments with the further development of

models of scenario development of the life cycle of innovations (biotechnologies) (Tytarchuk *et al*., 2020; Ilchuk *et al*., 2019; Madiyoh, Turan & Gürlük, 2021). Among such countries, the leading place is occupied by the United States. According to the marketing company Burrill & Company, in 2013 more than $ 65 billion dollars were allocated to U.S. scientific institutions for the development of biotechnological research, with an annual growth of almost $ 2 billion. About 80% of these funds were used to develop pharmaceutical biotechnology, and more than 20% ($ 15 billion) went to biotechnology companies in other industries. The next places are occupied by Japan ($ 7 billion), Canada ($ 3 billion) and EU countries ($ 15 billion). As noted by D. Grodzinsky, the International Consulting Agency Abercade estimated the volume of the world market for biotechnology in 2010 at more than $ 160 billion (Tytarchuk et al., 2020). According to other data, the global biotechnology market in 2020 will exceed $ 600 billion, and in 2025 it will reach $ 2000 billion (Abercade Consulting, 2015; Vakulich, 2014; Frost & Sullivan, 2014).

I. Kalayci cites the segmentation of biotechnological innovations by economic sectors, and substantiates the conclusion about their complexity and synergy in the agro-food sphere, bioenergy, veterinary medicine, animal breeding, genetics (Kalayci & Uzun, 2015). The typology of biotechnology by colour proves its relevance to all sectors of the economy and actually contributes to the conclusion of the final transition to the sixth technological mode (DaSilva, 2004; Rudenko *et al*., 2017). As a practical value and further development of biotechnology, scientists propose the creation of biotechnology clusters. One such cluster is planned in the Lviv region and will combine the biotechnology component, bioenergy, organic agriculture, food industry and industry enterprises of regional specialisation. The latter should be woodworking and forestry for industrial furniture enterprises (Vasyliuk, 2021). The innovation-active component of such a cluster or its core should be formed by research and educational institutions, among which the Lviv National University of Veterinary Medicine and Biotechnology named after S. S. Gzhytskyy, State Research Control Institute of Veterinary Drugs and Feed Additives, Institute of Cell Biology of the National Academy of Science of Ukraine, Institute of Animal Biology of the National Academy of Science of Ukraine and others, which is quite logical. The main advantages of such a cluster are a steady increase in demand for biotechnology products and a high level of efficiency in the functioning of each individual institution and the cluster as a whole (Vasyliuk, 2021).

Stable demand for biotechnology requires a transition to a new level in the sphere of pricing, as it is innovativeness and efficiency that are the main factors in price formation. In our opinion, the determination of the efficiency of biotechnological solutions or processes should be based on the main approaches to understanding the essence and properties of bioeconomics. N.I. Kravchuk and other scientists suggest using the following approaches: system approach; value chain approach and market approach (Kravchuk *et al*., 2018; Abuselidze, 2021). Due to their peculiarities and suitability for practical use, we believe that the value chain approach is optimal. In bioeconomics, this approach is used when evaluating technologies for the transformation of bio raw materials to create and further sell a new product. N.I. Kravchuk considers it acceptable for the solving of problems of the bio circular economy, allowing one "to use or use not used" by the further processing of raw materials or the organisation of wasteless production. The presence of certain limitations of this approach in solving other biotechnological problems, in our opinion, limits its use.

In agriculture, in particular in the study of animal breeding biotechnology, genetics, and reproduction, where the result of bio transformations are objects with new properties and high added value, its feasibility is high.

The market approach is quite interesting from the point of view of the institutional formation of the bioeconomic system, when state agencies and scientific institutions, business enterprises, market infrastructure work for a common goal, the realisation of which consists of ecosystem sustainability, growth of food supply, improvement of the population's well-being, etc. This approach is extremely difficult in terms of practical implementation and the ability to predict the results at the national level in conditions of uncertainty and lack of training (Levkina *et al*., 2019). In addition, the market approach requires comparison with an analogue, which is a trade secret and legally protected.

It is known that the performance of any system that includes biotechnology can be evaluated through quantitative and qualitative indicators, the individual composition of which is explained by the class of tasks to be solved.

In this publication, we propose a new approach to determining the efficiency of biotechnological processes in animal husbandry based on the study of the effect of technological parameters on the bio-object. Let us take a brief journey into the history of the use of biotechnology in animal husbandry. Such biotechnologies have been increasingly used to solve reproductive problems in animal husbandry since the second half of the 20th century. It should be noted that modern reproductology of farm animals is based

on the use of artificial insemination technologies; transplantation and cryopreservation of embryos and sperm; synchronisation of ovulation cycles, hormonal treatment of females to increase the number of embryos. There is a rapid development of technologies of intracellular fertilisation and embryo production in vitro with litter production; production of transgenic animals; cloning. Practical application has shown a high level of commercialisation by increasing the productivity of farm animals and solving medical problems. Commercialisation is mainly provided by alternative ways of procurement and transportation of animals, primarily by international trade in cryopreserved embryos for the purpose of conducting breeding research and rapid recovery of the animal population.

According to the results of our research, the cheapest and most technologically advanced method of embryo transplantation is the non-surgical method. It is the use of laser technique for such purposes that allow the creation of conditions for the rapid reproduction of valuable genotypes and trade of cattle embryos (Levkina *et al*., 2019; Levkina *et al*., 2022).

Scientific papers (Pankieiev, 2012; Binyameen *et al*., 2019) provide data on the volume of the world market of cattle embryo transplantation. Thus, in 2022 in North America more than 190 thousand transplants per year are planned; in South America - 120 thousand; in Asia - 92 thousand; in Europe - 100 thousand; in Oceania - 33 thousand; in Africa - 14 thousand. Consequently, the annual volume of this world market can exceed 550 thousand transplants per year, which

Table 1

Efficiency of Bovine Embryo Laser Fission Biotechnological Process by SCM Concept

Directions to increase the efficiency of biotechnology operation	Sources of efficiency increase	Indicators that have a direct impact on efficiency improvement	Impact on efficiency level
Reducing risks and increasing the accuracy of the operation	Use of high-precision tools and equipment	Volumes of operations performed Accuracy of instruments and equipment Number of defective embryos (delivered)	Increase Decrease
	Involvement of professionals	Work experience The level of relevant qualifications of specialists	Increase
	High level of technology	Compliance of indicators with reference samples	Increase
Process Automation	Setting up the biotechnology process	Process assembly line Duration of biotechnology process Stock level of raw materials Continuity of biotechnology process Production capacity	Increase
Source material viability	Compliance with sanitary norms	Sterility level Adherent level Viability level	Increase
	Level of embryo development	Number of injured embryos	Decrease
	Storage conditions	Optimal temperature Optimal pressure inside storage boxes	Increase
Implementation of biotechnology in a production environment	Compliance with the requirements of transplantation of bio-objects (recipient cows)	Optimal characteristics of technical means of implementation of processes	Increase

Source: Formed by the authors for the first time on the basis of research and publications (Levkina et al., 2019; Levkina et al., 2022).

is financially conditioned by a high level of cattle marginality, its biological features (suitability for non-surgical washout, transplantation, cryopreservation and cloning of embryos). Implementation of biotechnological methods of accelerated reproduction, storage and transportation of biological material for breeding requirements, high level of reproduction process efficiency in practice become more and more urgent in view of the low intensity of biological reproduction, inconvenience, high cost and duration of transportation of cattle.

To determine the level of efficiency of the above biotechnological processes, the concept of SCM (Supply Chain Management) has significant advantages and requires a comprehensive approach to the formulation of the main directions and sources of efficiency improvement. We propose to present it in the following form (table 1).

A detailed analysis of the directions and sources of increasing the efficiency of the above biotechnological process and the list of indicators proposed by the authors allow us to put forward a hypothesis about their homogeneity, interrelation and common origin. At the same time, the main conclusion is that the given indicators are related to the level of viability of the bio-object (embryo): optimal temperature or optimal pressure in the boxes during the storage of embryos, compliance with reference samples, as well as the level of sterility and others. That is, the main indicator of the efficiency of this biotechnological process is to ensure a high level of viability of the embryo and reduce the number of rejects, which is possible by using high-precision equipment whose parameters are set to not exceed the level of thermal stability of the bio-object (embryo). We propose to call it an integral index, which is a set of indicators from table 1 and technically can be reduced to the level of viable bio-objects.

Thus, the realisation of the goal of this publication, which is to develop theoretical and methodological foundations and practical recommendations for determining the efficiency of biotechnological processes with subsequent justification of technical parameters to ensure a high level of viability of biological objects, requires optimisation of the working parameters of technical means. We propose to solve the optimisation problem through the introduction of an integral efficiency indicator, a formalised version of which is the quality function, which is a logical continuation of our previous research.

Consequently, the application of the quality function in the biotechnological process of bovine embryo transplantation makes it possible to optimise the working parameters of the technical means of the biotechnological process in animal husbandry. With the use of additional software, such a process can be automated, which allows one to increase the number of conducted operations of embryo division without increasing the level of their traumatisation.

The analysis of scientific publications showed that the works (Penev & Andreev, 2020; Stoian & Putiatyn, 1982; Skoblo *et al*., 2020; Kravtsov *et al*., 2021) considered the issues of analysis and synthesis of systems containing mobile local sources of the physical field and proving the universality of the methodological approach to the calculation and optimisation of systems with distributed parameters. The issues of modelling processes occurring in bio-objects under the influence of them by a laser energy source have been studied by domestic and foreign scientists. However, they form the basis for the study of applied problems of bioeconomics of laser division of early elite embryos of farm animals and the subsequent use of viable separated parts of the embryo at artificial insemination stations (Csillag *et al*., 1988; Silaeva *et al*., 2018).

Let us formulate a quality criterion for the course of the thermal process in the embryo during its separation by a laser source and the corresponding restrictions on the variables.

The relationship between the temperature field and the moving laser source in general form:

$$A_T\{\ T[P(x,y,z,t),\ x,y,z,t]\ \}=0 \qquad (1)$$

Where A_T is the differential operator that describes the distribution of the temperature field;

T (x, y, z, t) - temperature field;

x, y, z - spatial variables;

t is the duration of the laser action;

P (x, y, z, t), a function describing the moving laser source.

The corresponding initial and limit conditions are set.

The locality of the source action is defined by the relation:

$$P(x,y,z,t)=\begin{cases}P(x,y,z,t),\ якщо\ (x,y,z)\in S,\\ 0, \qquad якщо\ (x,y,z)\in\overline{\Omega}\setminus S\end{cases}, \qquad (2)$$

where S - the carrier of the laser source;

$\overline{\Omega}=\Omega\cup\Gamma$, Ω, - internal points of the embryo;

Γ- external boundary of the embryo;

The amount of energy emitted by the source W during its action time is defined as:

$$W=\int_0^{t_u}\int_S P(x,y,z,t)\,ds\,dt, \qquad (3)$$

and the intensity of the source is defined as an integral characteristic of its carrier:

$$g(t) = \int_S P(x, y, z, t)ds. \quad (4)$$

The geometric shape S of the mobile laser source carrier is characterised by the type of source (spot, sphere, extended as a segment) and its geometric parameters: the spot or sphere radius, two dimensions of a rectangle for a flat extracted source, three dimensions for a volumetric extracted source and others.

The law of motion of the source is determined by the trajectory $s(t)$ and the speed of its movement along this trajectory.

On the basis of relation (1), let us formulate a functional, which formalises the value, put into the notion of the quality of the technological process of laser fission of embryos, and formalises the restrictions on the variables.

The value of the quality criterion of embryo fission is to ensure the thermal stability (viability) of its separated parts. This will be ensured if, in the technological process of laser division of the embryo, the maximum value of the temperature field of the embryo (its parts) will not exceed a given value that ensures the viability of the embryonic parts.

Functional quality of the technological process of embryo laser fission:

$$\Phi = \left| \max_{(x,y,z)\in\overline{\Omega},\ t\in[t_0 t^*]} T\,[P(x,y,z,t), x, y, z, t] - T^* \right| < \varepsilon, \quad (5)$$

Where T^* - the permissible value of the temperature field;

ε - deviation of the maximum value of the temperature field from the given permissible value;

t_0, t^*, - initial and final value of the duration of embryo separation;

The criterion of optimality of technological process of embryo laser separation on the basis of relation (5) is:

$$\left| \max_{(x,y,z)\in\overline{\Omega},\ t\in[t_0 t^*]} T\,[P(x,y,z,t), x, y, z, t] - T^* \right| \Rightarrow \min. \quad (6)$$

The notations remain the same as in the previous relations.

Note that a particular case of the function (5) of the quality of the technological process of embryo laser fission can be the criterion of not exceeding the temperature field in a given controlled point of a predetermined permissible value. In this case, the function (5) will look as follows:

$$\Phi = \left| T(x^*, y^*, z^*, t) - T^* \right| < \varepsilon, \quad (7)$$

Where (x^*, y^*, z^*) is the control point of the temperature field.

The optimality criterion in the case (7):

$$\left| T(x^*, y^*, z^*, t) - T^* \right| \Rightarrow \min. \quad (8)$$

Let us point out the restrictions on the process parameters.

Limitation on the power of the laser source:

$$W_{\min} \le \int_0^{t_u} \int_S P(x, y, z, t)dt \le W_{\max}, \quad (9)$$

Where $W_{\min}, W_{\max}$ are, respectively, the minimum and maximum values of power.

In the case where the power is a stationary function:

$$W_{\min} \le W \le W_{\max}, \quad (10)$$

Where $W = const$.

Limit the intensity of the laser source:

$$g(t)_{\min} \le \int_S P(x, y, z, t)ds \le g(t)_{\max}, \quad (11)$$

Where $g_{\min}, g_{\max}$ are the minimum and maximum values of intensity, respectively.

A particular case of the constraints (11):

$$g_{\min} \le g \le g_{\max}, \quad (12)$$

Where $g = const$.

Restrictions on the geometric parameters of the laser source carrier, for example for a chain-shaped or sphere-shaped carrier:

$$r_{\min} \le r_0 \le r_{\max}, \quad (13)$$

Where $r_{\min}, r_{\max}$ are the minimum and maximum values of the radius of the laser source, respectively.

In the case where the medium is three-dimensional rectangular, then the corresponding limit minimum and maximum values of the limits of its changes are set x_0, y_0, z_0:

$$x_{\min} \le x_0 \le x_{\max} \quad (14)$$

$$y_{\min} \le y_0 \le y_{\max} \quad (15)$$

$$z_{\min} \le z_0 \le z_{\max}. \quad (16)$$

Restriction on the trajectory of the laser source:

$$s(t) \in L^*, \quad (17)$$

Where L^* is the set of trajectories of the source motion.

Restriction on the velocity $v(t)$ of the source along the trajectory:

$$v(t)_{\min} \le v(t) \le v(t)\, x_{\max} \tag{18}$$

Where $v(t)_{\min}, v(t)_{\max}$ – are, respectively, the minimum and maximum values of the source velocity.

A particular case of the constraint (18) is the constraint:

$$v_{\min} \le v \le v_{\max}, \tag{19}$$

Where $v = const$.

Restriction on the temperature field gradient:

$$gradT(x.y.z.t) \le T^{**}, \tag{20}$$

Where T^{**} - the permissible value of the temperature field gradient.

Limitation of the temperature field value at a fixed point of the field control:

$$T\ (x,^* y^*, z^*, t) \le T^* \tag{21}$$

Where $(x,^* y^*, z^*)$ - temperature field control point; T^* - The permissible value of the temperature field at the control point.

The peculiarities of the optimisation problem in selecting the working parameters of technical means for the laser separation of embryos allow one to conclude that one cannot expect to obtain an exact solution of the problem. Therefore, it is advisable, based on the peculiarities of the object of research and simplification of restrictions, without losing the main goal of solving the problem of ensuring the quality of the technological process, to consider the possibility of applying approximate methods of synthesis of the main parameters of the process of laser separation of embryos.

For the averaged values of the thermal conductivity of the embryo α≈0.25 (Wt/m) K, specific heat capacity of the embryo c≈1.55 (kdj/kl)K, radius of beam r_0≈4мкм, embryo radius R≈150mkm, temperature field control at the point $r_1^* = r_0 + 0.1\ r_0^*$ (where r^{0*} - averaged blastomere radius), the number of blastomeres m=16, numerical calculations were performed to determine the power of the source, taking into account the allowable temperature T1*=49±0.30C. The corresponding value of the laser power is 2 Wt.

The heat dissipation calculations for P=2 watts are based on the assumption that the thermal conductivity of the embryo is close to that of water. Since an embryo consists of 80% water, this assumption is acceptable. In fact, it is done with a margin, because the presence of proteins in the embryo reduces the thermal conductivity, hence the resulting temperature distribution will be smaller than calculated. Figure 1 shows how the temperature changes as a function of the distance to the axis of the laser beam separating the embryo.

As we can see, the excess of the permissible temperature of 49 ^{0}C (damage zone) is ≈10 μm. This is an acceptable value for the full development of the remaining parts of the embryo.

To justify the possible areas of application of a particular laser in medicine, biology and veterinary

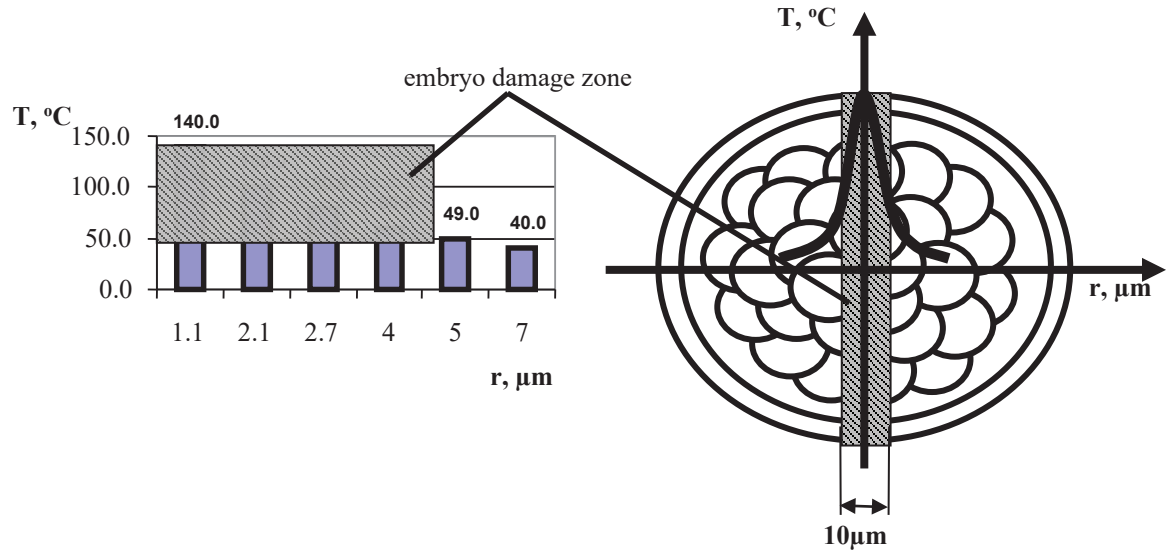


Figure 1. Temperature distribution in the controlled points of the embryo during laser beam fission.

Source: generated by the authors based on a schematic representation of the embryo by multi-photon imaging.

Table 2

Absorption spectra of the shell, perivitellated space, and blastomeres as components of the embryo

Shell	Perivitellated space	Melanin	Blastomeres
0.88	0.94		0.36
0.92	0.96	0.62	0.38
0.94	0.92	0.63	0.44
0.92	0.86	0.64	0.52
0.9	0.83	0.65	0.54
0.86	0.78	0.66	0.58
0.83	0.74	0.67	0.6
0.8	0.7	0.68	0.44
0.78	0.67	0.69	0.4
0.77	0.65	0.7	0.39
0.82	0.72	0.71	0.08
0.85	0.82	0.72	0.04
0.9	0.88	0.725	0.03
0.92	0.83	0.73	0.03
0.9	0.78	0.68	0.02
0.84	0.84	0.65	0.01
0.75	0.84	0.62	0.01
0.66	0.68	0.58	0.01
0.58	0.44	0.54	0.01
0.52	0.28	0.5	
0.44	0.2	0.45	
0.38	0.14	0.4	
0.34	0.1	0.41	
0.3	0.09	0.38	
0.27	0.09	0.37	
0.25	0.12	0.36	

Source: Obtained by the authors during the study (Supatto et al., 2011)

medicine, in addition to theoretical and experimental studies, an important prerequisite is, if possible, a broader knowledge of the spectral absorption characteristics of various bio-objects. Table 2 shows absorption spectra of the envelope, perivitellated space, and cells of blastomeres that are part of the embryo.

Based on the calculations of laser power, temperature distribution in the embryo under the action of laser radiation and absorption spectra, the use of a continuous argon laser with a radiation wavelength of 515 nm or 488 nm and adjustable power in the range of 0-2 V is justified. Laser beam as pulses of 1 ms or less duration; pulse energy ≈0.002 J; divergence 0.9 mrad. Our conclusions differ significantly from the recommendations (Supatto *et al.,* 2011), to use a picosecond pulse (~2 ps) infrared laser with a high repetition rate (80 MHz) for the manipulation of mouse embryos, which is related to the specificity of the bio-object and its size at a certain stage of development.

Thus, the efficiency of the biotechnological process of laser fission of bovine embryo increases due to the full automation of the fission process, and the maximum elimination of the "human factor". The use of mathematical apparatus in the process of creating a model of the biotechnological process and its solution based on the features of the bio-object itself and limitations on thermal assumptions

allow one to obtain the optimal set of parameters of technical means. Such a set and ratio of parameters correspond to the highest level of efficiency of a given biotechnological process, which is the level of viability of bovine embryos.

Conclusions

The definition of the concept of "bioeconomics" in terms of its connection to the economic mechanism in the implementation of biotechnology and the formation of a basis for the mechanism of sustainable development of the world economy was analysed. It was established that bioeconomics should be considered as a science that implies the use of biotechnology for the development of new technological processes and new products in order to ensure sustainable production and integration into different spheres of activity. The conceptual approach to bioeconomics as an innovative tool for solving a number of problems of a global nature: economic, social, food, medical, environmental, confirms its complexity and synergetic effectiveness.

The high rate of development of bioeconomics in all countries of the world, as well as the growth of the world market of cattle embryo transplantation, indicate a growing demand for biotechnological methods of accelerated reproduction, storage and transportation of biological material for breeding and production requirements.

Based on the analysis of the main directions and sources for increasing the efficiency of the biotechnological process under study, according to the SCM (Supply Chain Management) concept, it was found that the only indicator of efficiency is the level of viability of embryos. The criterion for selecting high-precision equipment is the fulfilment of the condition of not exceeding the thermal stability level of the object (embryo). Such an integral index can technically be reduced to the level of viable bio-objects (embryos).

The solution of the optimisation problem through the introduction of the integral efficiency index, the formalised version of which is a quality function, allows the working parameters of the technical means of the biotechnological process to be optimised in animal husbandry. The resulting set and ratio of parameters correspond to the highest level of efficiency of this biotechnological process, as the level of viability of bovine embryos.

Further development of the work concerns the refinement of mathematical models based on taking into account the structure of bio-objects, and due to these, the provision of proposals for more effective technical means of implementation of the biotechnological process.

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